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CHIROPTERAN COMMUNITY STRUCTURE AND SEASONAL DYNAMICS IN BIG BEND NATIONAL PARK

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Introduction

The activities of bats have important agricultural, environmental, and human implications. About 70% of bat species are insectivorous, and many consume insects that are harmful to crops and a nuisance to humans (Tuttle, 1988). Fruit and nectar-eating bats are essential to the pollination and seed dispersal of many tropical plant species, many of which possess agricultural and medicinal importance (Gardner, 1977). Furthermore, bats serve as indicators of environmental health because in general, they are potentially sensitive to environmental change. In terms of public health, bats are of interest as they harbor certain parasites and diseases, some of which are transmittable to humans and other mammals.

Recent declines in bat populations, particularly that of sensitive species, are attributable to habitat destruction, human disturbance, and improper management of roosting sites such as caves and abandoned mines which are often used by thousands or even millions of individuals (Fenton, 1997). Despite the increase in bat research over the past few decades, many areas within chiropteran ecology still remain poorly understood. Baseline data on habitat and roosting requirements, dietary preferences, seasonal habits, migration, community structure, and distributions are needed to elevate our understanding of many poorly understood species of bats, and to facilitate the formulation of conservation and management plans by researchers, wildlife managers, and land management agencies.

Study Area

Big Bend National Park (hereafter BBNP) is located in the Trans-Pecos region of Texas (Brewster County) where the Rio Grande changes course from southeast to northeast (Fig. 1). The park's area presently encompasses approximately 801,163 acres (3,244 square kilometers), including some of the most remote and wild areas remaining in the United States. The Rio Grande travels along the southern boundary of the national park for 107 river miles from Lajitas to La Linda, Texas. Dramatic topography (550 meters to 2,400 meters) in BBNP is provided by the Chisos Mountains clustered in the center of the park, and the surrounding sunken block of lowlands comprising the main body of the park. Average rainfall varies with elevation, thus the uplands receive about 46 centimeters of rain a year, while the desert floor averages near 25 centimeters annually (United States Department of the Interior, 1983). July, August, and September comprise the rainy season, typical of monsoon patterns exhibited in the desert southwestern United States. Average annual relative humidity is 50% (United States Department of the Interior, 1983). According to the data collected at weather stations within BBNP during the study period, temperatures recorded in the lowlands at Castolon and Boquillas weather stations (Fig. 1) during 1996–97 fluctuated from -13 to 46° C, with a mean annual temperature of 16°C. Daily temperatures obtained from the Chisos Mountains weather station (Fig. 1) during 1996–97 were more stable, ranging from -12 to 36° C, and the average annual temperature was 17° C.

Prior to the establishment of the national park in 1944, open grasslands invited ranchers to the Big Bend region. Over-grazing by domestic cattle was not apparent until the early 1940's, yet it eventually resulted in the destruction of the region's natural grassland habitat. Evidence of this effect remains apparent across the park, and many areas once dominated by grasses have been invaded by various desert shrubs.

The existing vegetation throughout the park is diverse and dependent upon the terrain. Plumb (1992) summarizes multiple studies describing the variety of plant assemblages that define the landscape in BBNP. Each description differs, often serving the purpose of a particular study of biotic associations. Wauer's (1971) description of vegetation associations in BBNP culminated from his observations of breeding bird distributions among particular plant communities. This biotic association approach to classifying vegetation type was used by Easterla (1973*a;* 1973*b*) in his correlation of bat distributions with a given plant community in BBNP. Easterla (1973*a;* 1973*b*) reports: "although the distribution of most bats is not directly influenced by a specific plant habitat, related climatic factors such as temperature, precipitation, and effective moisture probably have a direct effect upon bat distributions." Sawyer and Lindsey (1971) suggest that the vegetation found in a particular region is indicative of these general climatic characteristics. How-

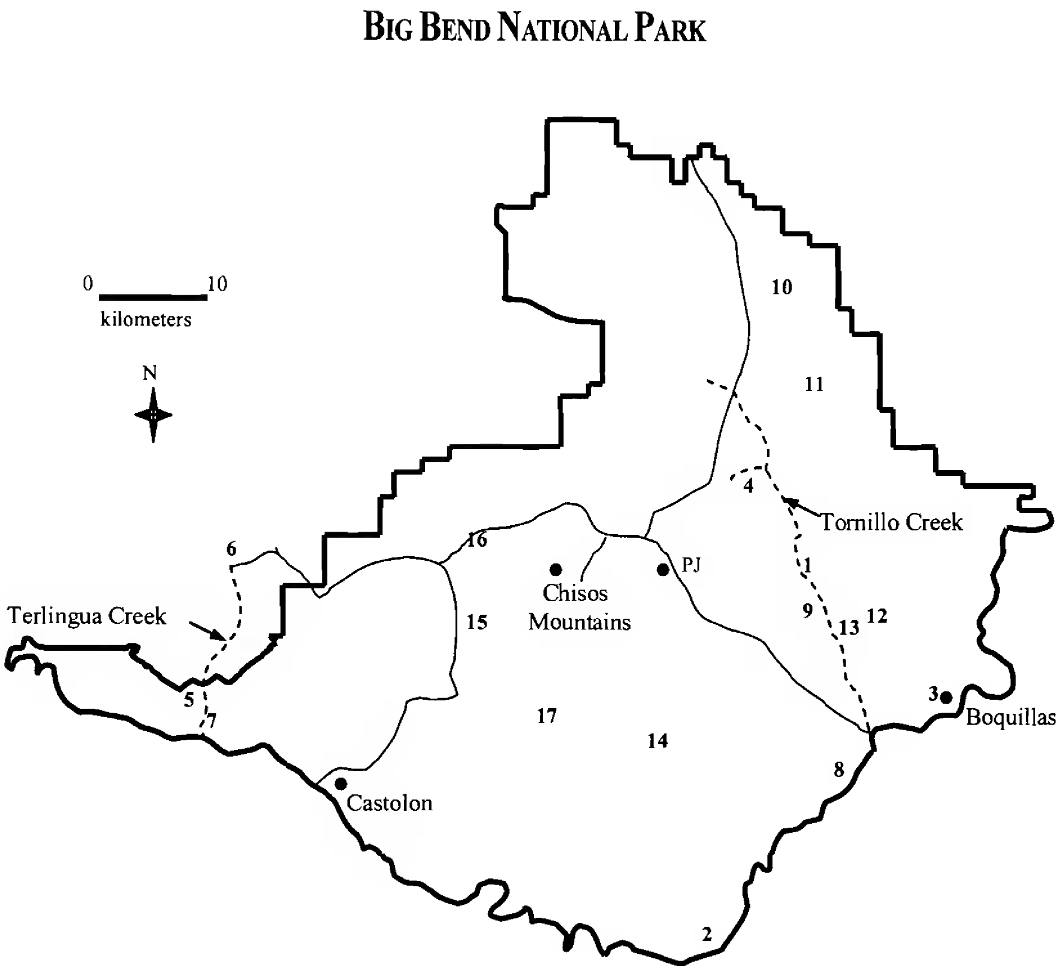


Figure 1. Map of Big Bend National Park, Texas. Numbers indicate netting localities listed in Table 2. Closed circles indicate named weather stations. Solid lines indicate park roads. Dashed lines indicate creeks. PJ=Panther Junction.

ever, Findley (1993) cautions that due to their highly mobile nature, bat species present at any one site undoubtedly reflect the fauna of a much larger area.

The scheme proposed by Wauer (1971) currently stands alone in correlating certain plant communities with the distribution of birds in Big Bend. The capability of powered flight in bats is unique among mammals, therefore the activities of bats are more aptly correlated with those of birds than with other mammals. Aside from this, Wauer's system of classifying plant habitats is used here for convenience in comparing chiropteran community structure at sites sampled in this study with those sampled by Easterla in the same vegetation zone 30 years before. Three of the five vegetation zones described by Wauer (1971) and given in Table 1 were sampled for their representative bat fauna during this study (River Floodplain-Arroyo, Shrub Desert and Sotol-Grassland).

Water Resources

Bats are often seen foraging over the Rio Grande and other numerous water sources found throughout the park. Two tributaries to the Rio Grande, which flow only during or following heavy rains, drain this region. Tornillo Creek drains the arroyos to the east of the Chisos, and Terlingua Creek collects runoff west of the Chisos (Fig. 1). Despite its arid environment, the park is stippled with at least 180 springs, seeps, and wells that serve as watering holes for the surrounding wildlife (United States Department of the Interior, 1983). Most are located within the grasslands and on the lower slopes of the Chisos Mountains. Many are choked by dense vegetation, challenging the flight dynamics of even the most agile bats, while others provide large open pools that are easily accessible to bats and other animals for drinking. Spring sizes during the sampling period ranged from 0.5 centimeters deep with just a few square centimeters of surface area to a string of pools over 40 centimeters deep, 70 meters long and 12 meters wide (personal observation by J. L. Higginbotham). The amount of water found at a particular spring may vary greatly from season to season, or from year to year, and spring flow is highly dependent upon rainfall. Bats rely heavily on springs, the Rio Grande, and its tributaries nearly year-round for drinking. Species of bats that specialize in water-surface foraging further utilize these water resources as sources of insect prey.

Species Diversity

The geographical location of BBNP provides the opportunity to study a unique mixture of species within the convergence of the Nearctic and Neotropical zoogeographic regions. Twenty chiropteran species from four families and 12 genera have been reported from BBNP (Bailey, 1905; Borell, 1939; Borell and Bryant, 1942; Taylor et al., in litt.; Constantine, 1961; Easterla, 1968; 1970; Higginbotham et al., 1999). Several species of bats known from Texas are unique to the Big Bend region in Texas; these include the Mexican long-nosed bat (*Leptonycteris nivalis*) (Easterla, 1973*a;* 1973*b*; Mollhagen, 1973), the spotted bat (*Euderma maculatum*) (Easterla, 1970), and the pocketed free-tailed bat (*Nyctinomops femorosaccus)* (Easterla, 1968; Higginbotham et al., in press).

Several mammal investigations have been conducted in the region, although most were brief, and some largely ignored bats. Between 1905 and 1966, 13 species of bats were reported (Bailey, 1905; Borell and Bryant, 1942; Taylor et al., in litt.; Denyes, 1956; Constantine, 1961; Judd, 1967). Easterla (1973*a;* 1973*b*) conducted a thorough investigation of the ecology of Chiroptera in BBNP from 1967–71, providing a wealth of new information on the 18 species that he observed at 32 sites in five vegetation zones. Investigations conducted prior to the study reported herein (Bailey, 1905; Borell and Bryant, 1942; Taylor et al., in litt.; Constantine, 1961; Judd, 1967; Easterla, 1973*a;* 1973*b*) were conducted primarily during the summer months and excluded information on bat activity during the remainder of the year. The work presented herein summarizes the efforts of year-round sampling, allowing: (1) the investigation of the seasonal activity and seasonal abundance of all bat species in the lowland regions; (2) the construction of hypotheses concerning the migration or hibernation of species that were found in low abundance, or altogether absent in winter; and (3) the study of the reproductive habits

Table 1. Vegetation associations in BBNP (after Wauer, 1971)

Habitat	Plant Associations	Elevation
I. River Floodplain-Arroyo	Mesquite-willow-common reed-cottonwood and mesquite acacia	550 to 1,220 m
II. Shrub Desert	Lechuguilla-creosote-cactus	550 to 1,060 m
III. Sotol-Grasslands	Sotol-grasses	980 to 1,680 m
IV. Woodlands	Deciduous woodland and pinyon-juniper-oak woodland	1,100 to 2,400 m
V. Moist Chisos Woodlands	Arizona cypress-pine-oak	1,770 to 2,190 m

and seasonal differences in the observed sex ratios of Chiroptera in BBNP. Moreover, this work reports an investigation of the bats inhabiting desert lowland regions in BBNP with regard to community structure, and remarks on the general population trends of bats in BBNP over the last 30 years.

METHODS

Study Sites

Seventeen sites in three lowland vegetation associations as described by Wauer (1971) were sampled in this study. These are listed in Table 2 along with the corresponding vegetation association and type of water source, if any, present at the site. An initial focus of this investigation was to provide information on rare or uncommon species found primarily within the lower elevations of BBNP (*Euderma maculatum*, *Nyctinomops femorosaccus*, *Nyctinomops macrotis*, and *Eumops perotis*). For this reason, no upland sites (Chisos Mountains) were sampled. Universal Transverse Mercator (UTM) coordinates for each site are given in Appendix 1.

Measures of the relative abundance of lowland species of bats obtained from this study were compared to those calculated by Easterla (1973*a;* 1973*b*) from data he gathered from 1967–71 to investigate population trends over the last 30 years in BBNP. Additionally, the capture data collected at the most frequently sampled localities during this study were compared to each other to propose hypotheses regarding the differences observed.

Sampling Strategy

The fieldwork for this study was conducted over thirty months, beginning in March 1996 and continuing through September 1998. Sampling was conducted monthly March–October 1996 and March–November 1997. The 1998 field season began in January and field work was carried out monthly through June, with additional data from September.

In the desert environment, erecting nets over water sources to capture flying bats is an effective way of sampling the local bat population. Springs, streams and other water sources are often ephemeral in the desert lowlands of BBNP as a result of periodic flash flooding and long periods of drought. Only the most reliable water sources (Table 2) were sought as consistent sampling sites.

In this study, the lowland sites sampled by Easterla (1973*a;* 1973*b*) were explored as possible netting localities occasionally to discover that many of these water sources no longer produced or held water, or were choked with vegetation, and therefore unsuitable for mist netting. Only three lowland sites were shared between this study and Easterla's (1973*a;* 1973*b*); Rio Grande Village *Gambusia* pools, Ernst Tinaja, and Tornillo Creek pools at Hot Springs.

Capture Methods

All bats were captured in mist nets strung across water sources, roadways, canyon floors, and once, a roost opening. Nets were typically positioned perpendicular to the flow of water over streams or springs. Nets were positioned across the largest breadth of the water source at larger bodies of water (Rio Grande, Tornillo Creek, Terlingua Creek, Rio Grande Village Gambusia pools, and Ernst Tinaja), or at the spot most accessible for tending the nets. All nets were seven feet high and ranged in length from 18 to 42 feet. Collapsible tent poles or thin conduit guyed with twine tied to rocks or shrubs held nets erect.

Usually three or four nets were set prior to dusk and tended until dawn during the summer months. Bat activity in the spring, fall, and winter declined with decreasing temperatures, and often nets were closed early as a result. Mist netting was usually concentrated around the two-week period surrounding the new moon of each lunar cycle when moonlight was dimmest, or at times when a brighter moon was not high in the sky, as netting activity appeared to be more productive during these periods.

Measurements

Upon capture, each bat was weighed to the nearest gram. Standard morphological measurements for all bats were recorded, including forearm length, hind foot, ear, and testes length and width (reproductive males). A summary of these external measurements is listed in Appendix III. Other measurements taken

Table 2. Vegetation associations and water source characteristics at 17 sampling localities in Big Bend National Park.

Sampling Locality	Vegetation Association	Water Source Type
1. Banta Shut-in	River Floodplain	Spring
2. Cross Canyon on the Rio Grande	River Floodplain	River
3. Gambusia Pools	River Floodplain	Pool
4. Menagerie Springs	River Floodplain	Spring
5. Terlingua Abaja	River Floodplain	Spring
6. Terlingua Creek & Hwy. 170	River Floodplain	Creek
7. Terlingua Creek at Rio Grande	River Floodplain	River
8. Tornillo Creek at Hot Springs	River Floodplain	River
9. Carlotta Tinaja	Shrub Desert	Tinaja
10. Dagger Flat Canyon	Shrub Desert	Dry Arroyo
11. Dagger Flat Road	Shrub Desert	Puddle
12. Ernst Canyon	Shrub Desert	Tinaja
13. Ernst Tinaja	Shrub Desert	Tinaja
14. Glenn Springs	Shrub Desert	Spring
15. Cattail Falls	Sotol Grassland	Creek
16. Croton Springs	Sotol Grassland	Spring
17. Fresno Creek	Sotol Grassland	Creek

Note: The word "Tinaja" is Spanish for "earthen tank" and is referred to here as pools of water collected on bedrock.

when species identification was a concern were total body length, third metacarpal length, thumb length, and width and length of the rostrum. All measurements were taken with calipers and recorded to the nearest tenth of a millimeter. The time of capture was recorded for each individual in standard time. Beginning in March of 1997, all adult *Nyctinomops femorosaccus*, *Nyctinomops macrotis*, and *Eumops perotis* were marked proximal to the wrist with individually numbered, plastic split-ring bird bands manufactured by Avinet, Inc. *Nyctinomops* spp. and *Eumops perotis* were fitted with 2.8 millimeter and 4.0 millimeter bands respectively. This practice ceased beginning early in the spring of 1998, as possible injury to the bats became a concern.

Sex and Age Determination

Bats were aged by trans-illuminating the metacarpal joint from the dorsal side to inspect for evidence of cartilage at the epiphyseal joint (Anthony, 1988). Individuals showing evidence of cartilage were categorized as juveniles. Those captured in the winter or early spring, and showing at least some evidence of cartilage at the joint, were classified as sub-adults. All others were recorded as adults. Reproductive condition was recorded for each bat, excluding most *Tadarida brasiliensis*. Males were inspected for evidence of testicular descent. Females were checked for signs of pregnant or post-partum conditions and were classified as pregnant, lactating, post-lactating or non-reproductive. Pregnancy was determined by swelling and firmness in the abdomen, and/or by feeling for the bones of the fetus. Females were considered to be lactating when milk could be expressed from the nipples, or post-lactating when nipples were bare and enlarged, yet did not express milk.

Identification of Problem Species

Myotis californicus is difficult to distinguish from *M. ciliolabrum* in the field. Positive identification of either species in the field is unreliable in areas where the two occur sympatrically. The aid of acoustical sampling equipment can be a useful tool for field identification since the two species echolocate at distinctly different frequencies (O'Farrell, 1997). Morphologically, they significantly differ only in a few skull characteristics that are difficult to determine in the field without comparing the two species simultaneously or collecting them as museum specimens (Bogan, 1974; van Zyll de Jong, 1984). However, a lack of consensus seems to exist on the best way to distinguish the two species across their widely sympatric range on any basis, because much intraspecific morphological variation in specimens of *M. californicus* seems to exist in Arizona, New Mexico, Texas, and Mexico (Barbour and Davis, 1969; Anderson, 1972; Bogan, 1974; Findley et al., 1975).

Constantine (1998) recently suggested an obvious external character useful for distinguishing these two species of Myotis. Specimens of both species taken from the Mojave Desert in California were analyzed. Constantine (1998) suggests that specimens of *M. ciliolabrum* from the Mojave Desert display a 1.5–2.5 millimeter extension of the tail beyond the uropatagium (tail membrane) that is absent in specimens of *M. californicus* from the same region. Apparently this character was originally used to delineate the two morphologically, yet has remained overlooked for the past century (Constantine, 1998). As this information was only recently rediscovered, only voucher specimens considered as either *M. ciliolabrum* or *M. californicus* collected during this study were examined for this character.

For field diagnosis, some external characters outlined by Schmidly (1991) were used to determine species in lieu of an ideal system for distinguishing the two in west Texas. Measurements would often conflict with the character key, with a particular individual exhibiting two of three morphological characters outlined in the key. This presented a frustrating problem in assigning a bat as *M. californicus* or *M. ciliolabrum* in the field since collecting all bats captured in this group was not possible in the national park.

Due to the problematic identification of these two species of Myotis, field unknowns were identified as *M. californicus*, the more common of the two species in BBNP (Easterla 1973*a;* 1973*b*). Generally, these individuals displayed a pelage coloration that tended to be reddish rather than brownish, possessed thumbs smaller than or close to 4.0 millimeters, and exhibited square rather than rectangular rostrums. The latter two are morphological characteristics noted as important in distinguishing the two according to Schmidly's (1991) key. Another helpful character, the slope of the braincase (Bogan, 1974; van Zyll de Jong, 1984), was difficult to evaluate as being either sharply rising or gradually sloping without comparative material at hand. Based on these criteria, *M. ciliolabrum* was not encountered, yet is mentioned here to acknowledge the potential misidentification of some individuals that were released.

Voucher Specimens

Eighteen voucher specimens were collected during the course of this survey. Specimens were prepared when bats died upon capture, if skeletal material was necessary to confirm species identification, or if vouchers were important as seasonal or distributional records. Muscle and/or liver tissue was collected from most specimens. Vouchers were prepared as study skins and skulls and were originally housed in The Collection of Vertebrates at The University of Texas at Arlington. They have since been accessioned into The Angelo State Natural History Collection (Angelo State University, San Angelo, Texas), and remain the property of the National Park Service. Appendix 2 lists the UTM coordinates of collection localities, museum numbers, dates of collection, and sex of all voucher specimens.

Locality and Environmental Data

When possible, the following information was collected for each study site: elevation in meters, geographical coordinates based on the Universal Transverse Mercator system (acquired using a global positioning system or USGS map; Appendix 1), and structural characteristics. The following environmental and lunar information was recorded each netting night: temperature in degrees Celsius, wind speed in mph (either measured using a Wind Wizzard™ or estimated), degree of cloud cover, presence or absence of precipitation, and lunar phase. Minimum and maximum temperatures and precipitation levels were obtained daily by the National Park Service at four different weather stations (Fig. 1) within the park: Panther Junction (elevation 1130 meters); Basin (elevation 1600 meters); Boquillas (elevation 560 meters); Castolon (elevation 640 meters). Lowland rainfall data in 1996 and 1997 were obtained from the Castolon and Boquillas weather stations.

Data Analysis

Data obtained in the field were organized and sorted in a Microsoft Excel 97 spreadsheet database and the program was used to graph seasonal occurrence and age and sex ratios. These seasonal data were plotted across months of the year for each species, with no distinction between years.

Species richness and diversity applies to the number and kinds of species present in an area, whereas species composition refers to the relative abundance of each species (Hall and Willig, 1994). The relative abundance of lowland bat species was estimated by dividing the number of netting nights each species was encountered by the overall number of sampling nights (94) conducted during this study. Throughout this work, relative abundance is sometimes referred to as occurrence frequency. Comparisons were made regarding the percentage of captures, relative abundance of species, or numbers of individuals obtained during Easterla's (1973*a;* 1973*b*) investigations in BBNP and data obtained in this study. These comparisons excluded data collected by Easterla (1973*a;* 1973*b*) in the Chisos Mountains, localities in Mexico, and roost populations estimated by him, as the data presented herein are based on lowland mist net captures alone.

Capture data for each species is presented as the total number of individuals captured per hour of netting effort in an attempt to standardize this data.

Ecologists have devised a number of similarity coefficients in an attempt to compare community structure among distributions of organisms. Cheetham and Hazel (1969) provided a summary of the more than 20 binary similarity coefficients in the literature. We employed Jaccard's (1912) coefficient of similarity to evaluate the chiropteran community structure among the different sampling localities.

The coefficient of Jaccard is an index based on the presence-absence relationship between the number of species in each community and the total number of species. The coefficient of Jaccard is expressed as:

$$S_j = \frac{a}{a + b + c}$$

and considers three parameters: a, the number of species shared between two localities; b, the number of species present in the first locality but not the second; and c, the number of species in the second locality but not the first. The Jaccard's indices are considered here as descriptors that illustrate the relative similarity in chiropteran community structure between each pair of sites sampled in BBNP during this study. The coefficient ranges in value from 0 to 1.0 with 1.0 indicating complete similarity between two sampling areas.

An average-linkage clustering analysis was performed using the calculated Jaccard's indices for each pair of sites. We then used the unweighted pair-group method using arithmetic averages (UPGMA) to construct branching tree diagrams clustering the sites most similar in species composition.

RESULTS AND DISCUSSION

Nineteen hundred seventy eight bats of 17 species were captured at 17 sites. Netting effort consisted of 1281.5 net hours during 94 netting nights. Species of bats and numbers of individuals captured at a given site are grouped by vegetation zone and listed in Tables 3 (River Floodplain-Arroyo), 4 (Shrub Desert), and 5 (Sotol-Grasslands). Annual and total numbers of each species captured are summarized in Table 6. The differences observed in capture results for each species may be explained by factors such as netting biases (not all species are equally obtainable with mist nets), unequal sampling (all localities were not evenly sampled and some were only visited certain times of year), and abundance of a species in BBNP. The relative abundances of each species and the number of sites at which they were encountered are summarized in Table 7. Original field data are available from the authors.

Seasonal occurrence records for the state of Texas were recorded for 10 species and are illustrated in Figure 2. Reproductive data were recorded for females (with the exception of *Tadarida brasiliensis* due to the volume of captures of this species and the limited processing time beginning in 1997). These data are summarized in Figure 3. Species with limited or no reproductive data were excluded.

A list of chiropteran species occurring in BBNP is given in Table 8. The list includes *Myotis volans*, a highland species that is known from the Chisos Mountains, and *Myotis ciliolabrum*, which is apparently rare in BBNP. Neither of these species of Myotis was captured during this lowland study. Also listed is *Lasiurus borealis*, which is considered as extremely rare based on a single park record taken from a cave in the Chisos Mountains in 1938 (Big Bend Natural History Association, 2000). This species was not encountered during this investigation or Easterla's (1973*a;* 1973*b*), and its occurrence in BBNP is questionable (Easterla, 1975) or perhaps accidental. An additional species not referenced in previous park listings is *Lasiurus xanthinus*. Four individuals captured during this survey represent the first records of this species for BBNP, and the state of Texas (Higginbotham et al., 1999).

Detailed discussions regarding each species encountered in this study follow. These accounts are summaries of the findings presented herein, with references to past investigations of each species in BBNP.

Family Mormoopidae
Mormoops megalophylla (Peters)
Ghost-faced Bat

Constantine (1961) was first to encounter this bat in 1959 in BBNP. The National Park Service considers this bat fairly common in BBNP (Big Bend Natural History Association, 2000). Ninety-seven individuals were captured at nine sites within the three plant habitats sampled, although they were captured in greater numbers in the river floodplain and shrub desert habitats (Tables 3, 4 and 5). *Mormoops megalophylla* represented 4.9% of all captures and ranked fifth in relative abundance (Tables 6 and 7).

During this study, *M. megalophylla* was encountered every month beginning 18 March through 30 August, and on 12 October. Gaps in the known seasonal occurrence of this species in Texas were filled during April (Fig. 2). Most captures took place in May and July (Fig. 4). It is unknown if this bat overwinters in Big Bend due to the lack of winter records from the region. A recent survey of the mammalian fauna conducted at nearby Big Bend Ranch State Park (hereafter BBRSP) found *M. megalophylla* active only during the spring and summer months (Yancey, 1997). Hibernating populations have been documented in caves along the Edwards Plateau, and it has been suggested that migration between these two regions may occur (Schmidly, 1991). Suitable roosting habitat (caves and mines) located throughout BBNP may serve as a winter retreat for this species, yet this has not been established. Pregnant individuals were taken 25 April–14 July and the only lactating individuals were found in July (Fig. 3). Four juvenile females were captured between 17 June and 30 August (Fig. 3). The sex ratio in *M. megalophylla* was 92% females and 8% males (Fig. 5). The scarcity of males that were encountered in this investigation corresponds to Easterla's (1973*a;* 1973*b*) findings where males comprised 3% of captures of *M. megalophylla*. Yancey (1997) found only females at BBRSP.

Table 3. Summary of captures in the River Floodplain-Arroyo plant habitat.

	Banta Shut-In		Cross Canyons	Gambusia Pools	Menagerie Springs			Terlingua Abaja			Terlingua Creek & Hwy. 170	Terlingua Cr. at Rio Grande	Tornillo Cr. at Hot Springs
Species	1996 (3)	1997 (3)	1996 (1)	1996 (2)	1996 (5)	1997 (18)	1998 (5)	1996 (2)	1997 (13)	1998 (2)	1997 (1)	1998 (2)	1996 (1)
Mormoops megalophylla	6			1	3	8	2					1	
Leptonycteris nivalis													
Myotis velifer									1				
Myotis yumanensis			1			1			8	3		28	
Myotis thysanodes													
Myotis californicus	3		1	2	1	1			2				
Pipistrellus hesperus	19			8	7	15	5		4			4	
Eptesicus fuscus					1	2						1	
Lasiurus cinereus	2	1			3	6		1				1	
Lasiurus xanthinus					1	2	1						
Euderma maculatum			1				1						
Corynorhinus townsendii													
Antrozous pallidus	23		1	8	6	20	1	1	5				
Tadarida brasiliensis	10	18	10	2	103	564	5	6	70		4	2	2
Nyctinomops femorosaccus	1	1	2		39	182	16		17			1	
Nyctinomops macrotis					13	35	7		29		1		
Eumops perotis			2		23	53	5		5				

Note: Numbers in parentheses indicate number of netting nights conducted at a particular locality in the corresponding year.

Table 4. Summary of captures in the Shrub Desert habitat.

Species	Carlotta Tinaja	Dagger Flat Canyon	Dagger Flat Road	Ernst Canyon	Ernst Tinaja			Glenn Springs		
	1997 (2)	1996 (1)	1996 (1)	1996 (1)	1996 (7)	1997 (3)	1998 (2)	1996 (7)	1997 (1)	1998 (2)
Mormoops megalophylla	6				2			44	16	3
Leptonycteris nivalis								2		
Myotis velifer					6		2	24		1
Myotis yumanensis								4	1	
Myotis thysanodes										1
Myotis californicus				1	10	2		4		
Pipistrellus hesperus	12		1		52	21	11	2	1	
Eptesicus fuscus					5		1	12		3
Lasiurus cinereus					1			8		2
Lasiurus xanthinus										
Euderma maculatum										
Corynorhinus townsendii		5			5	2				
Antrozous pallidus	7	3	1	4	96		26	26	1	1
Tadarida brasiliensis	1				3			33		
Nyctinomops femorosaccus										
Nyctinomops macrotis										
Eumops perotis										

Note: Numbers in parentheses indicate number of netting nights conducted at a particular locality in the corresponding year.

Mormoops megalophylla was more often encountered over water in rocky canyons than in open riparian situations. As Findley et al. (1971) has suggested, these bats are agile fliers, and seem to have little difficulty maneuvering through constricted corridors where nets are set. This ability likely contributed to their usage of nine out of 17 sites sampled during this investigation.

Family Phyllostomatidae
Leptonycteris nivalis (Saussure)
Mexican Long-nosed Bat

Borell and Bryant (1942) first reported this species within the current boundary of BBNP from Mt. Emory cave in the high Chisos Mountains. *Leptonycteris nivalis* is considered uncommon in BBNP according to the National Park Service (Big Bend Natural History Association, 2000). It was ranked among the lowest in the relative abundance of bats during this investigation, comprising only 0.1% of captures (Tables 6 and 7). This species is listed as endangered by the United States Fish and Wildlife Service (Schmidly, 1991), and has been captured in the United States only in BBNP and in the adjacent Chinati Mountains of Presidio County (Mollhagen, 1973), which represents the northern periphery of its known range (Hensley and Wilkins, 1988). The summer colony occupying Emory Peak Cave is the only known roosting colony of this species in the United States. This migratory species typically arrives in Big Bend from Mexico in June to feed on the nectar and pollen of the park's flowering century plants (*Agave harvardiana*) found in the Chisos Mountains and the surrounding foothills (Easterla, 1973*a;* 1973*b*).

Two pregnant females were captured on 25 April 1996 prior to the flowering of the century plants. Both individuals were obtained at Glenn Springs (Table 4), a shrub desert site located along the southern edge of the Chisos foothills. These spring captures represent a seasonal occurrence record for this species in the United States. Prior to this survey they had not been captured before the month of June (Fig. 2). It is not known what these early migrants were feeding on prior to the annual blooming of the century plants, yet Easterla (1972) suggested that lechuguilla (*Agave lecheguilla*) might be an important food plant for these bats at the lower elevations. However, *L. nivalis* ap-

Table 5. Summary of captures in the Sotol-Grasslands habitat.

Species	Cattail Falls 1996 (1)	Croton Springs 1996 (2)	Fresno Creek 1996 (1)
Mormoops megalophylla	3		2
Leptonycteris nivalis			
Myotis velifer	1		1
Myotis yumanensis			
Myotis thysanodes		1	
Myotis californicus	2	1	
Pipistrellus hesperus	6	1	
Eptesicus fuscus	3		1
Lasiurus cinereus			
Lasiurus xanthinus			
Euderma maculatum			
Corynorhinus townsendii			5
Antrozous pallidus	5	2	10
Tadarida brasiliensis			
Nyctinomops femorosaccus			
Nyctinomops macrotis			
Eumops perotis			

Note: Numbers in parentheses indicate number of netting nights conducted at a particular locality in the corresponding year.

pears somewhat restricted to the uplands in the summer months, presumably due to its preference for available nectar and pollen from the century plants more abundant in the Chisos uplands and foothills. Ninety-three percent of *L. nivalis* captured in Easterla's (1973*a;* 1973*b*) survey were taken at Emory Cave in the Chisos, only 10 individuals were netted in the lowlands.

The presence of *L. nivalis* in BBNP fluctuates from year to year, and they may be absent altogether in some years (Easterla, 1972; Easterla, 1973*a;* 1973*b*; Koch, 1948). Annual fluctuations in the availability of resources across their Mexican range may account for this. Big Bend is located on the northern edge of their range, and therefore Mount Emory Cave likely serves as spill over habitat during years of high population and/or low food availability in Mexico (Easterla, 1973*a;* 1973*b*). It is possible that the early arrival of *L. nivalis* from Mexico in 1996 was provoked by the unusually dry conditions that prevailed across much of northern Mexico. In addition, both females en-

Table 6. Summary of mist net captures in Big Bend National Park (1996-1998). Species are listed in descending order of capture frequency.

Species	1996	1997	1998	Total	Percent of all captures
Tadarida brasiliensis	165	667	8	840	42.5
Nyctinomops femorosaccus	40	202	17	259	13.1
Antrozous pallidus	185	34	28	247	12.5
Pipistrellus hesperus	115	34	20	169	8.5
Mormoops megalophylla	61	30	6	97	4.9
Eumops perotis	23	60	5	88	4.4
Nyctinomops macrotis	13	65	7	85	4.3
Myotis yumanensis	4	11	31	46	2.3
Myotis velifer	32	1	3	36	1.8
Myotis californicus	24	3	3	30	1.5
Eptesicus fuscus	22	2	5	29	1.5
Lasiurus cinereus	15	7	3	25	1.2
Corynorhinus townsendii	15	2	0	17	0.9
Lasiurus xanthinus	1	2	1	4	0.2
Euderma maculatum	0	1	1	2	0.1
Leptonycteris nivalis	2	0	0	2	0.1
Myotis thysanodes	1	0	1	2	0.1
	718	1121	139	1978	100

Table 7. Relative abundance of lowland bat species in Big Bend National Park (1996-1998). Species are listed in descending order of the number of sampling nights they were encountered.

Species	Number of localities encountered	Number of nights encountered	Percent of nights encountered
Tadarida brasiliensis	12	52	55
Antrozous pallidus	14	45	48
Pipistrellus hesperus	11	44	47
Nyctinomops femorosaccus	5	33	35
Mormoops megalophylla	9	26	28
Eumops perotis	3	23	24
Nyctinomops macrotis	3	20	21
Myotis californicus	10	20	21
Lasiurus cinereus	6	14	15
Eptesicus fuscus	6	13	14
Myotis yumanensis	5	13	14
Myotis velifer	5	12	13
Corynorhinus townsendii	3	7	7
Lasiurus xanthinus	1	4	4
Euderma maculatum	2	2	2
Myotis thysanodes	2	2	2
Leptonycteris nivalis	1	1	1

Note: Relative abundance is based on 94 netting nights where $^{n}/_{94} \cdot 100$ = percent of nights encountered and n = number of nights encountered.

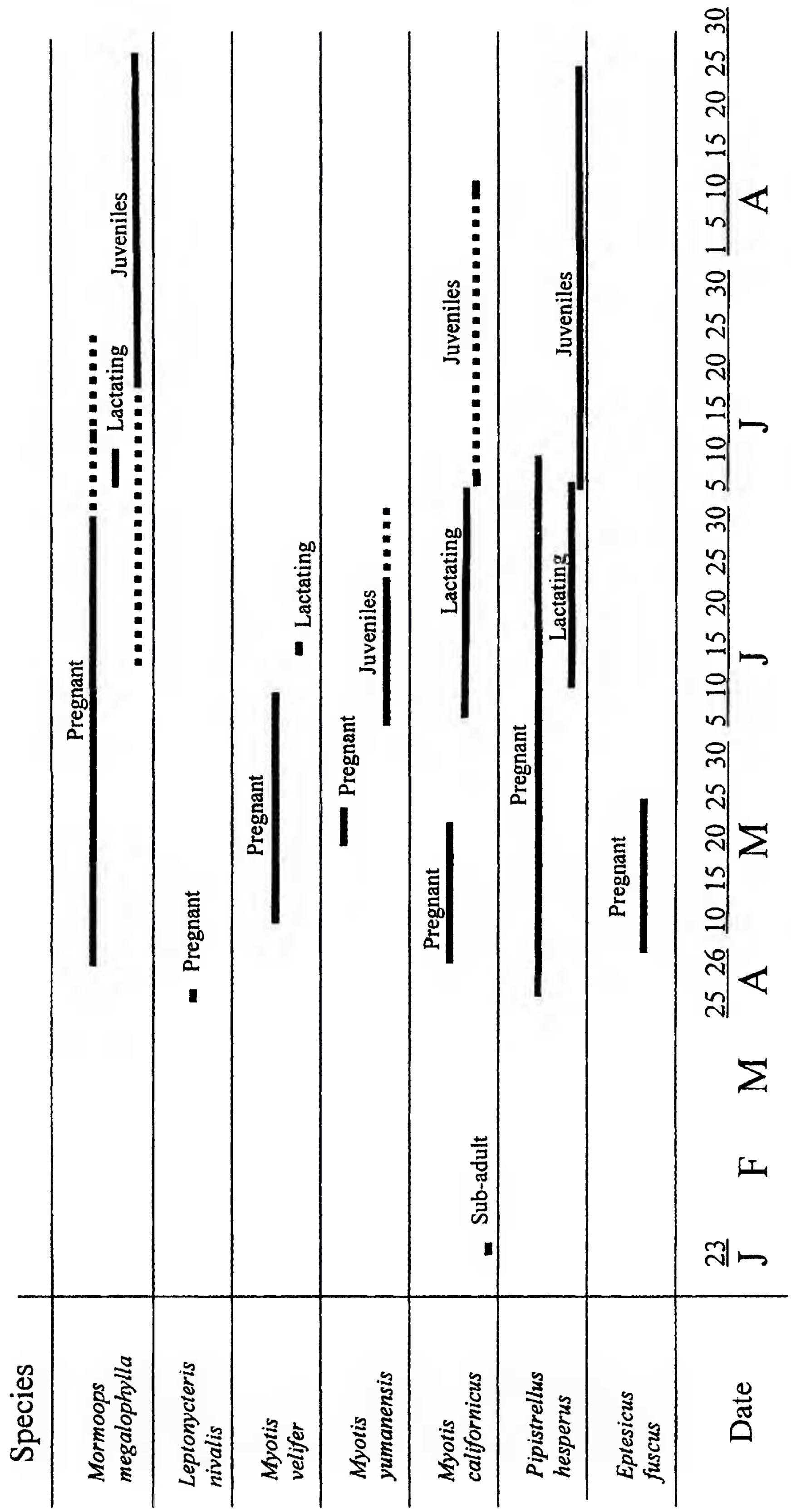
countered at Glenn Springs were observably pregnant and near term (Fig. 3). This conflicts with reports that they likely give birth in Mexico before arriving in Big Bend (Easterla 1973*a*; 1973*b*). Wilson (1979) proposed that the breeding season occurs in April, May and June. The capture of two pregnant females in April suggests the breeding season may begin earlier. During six visits to Mt. Emory Cave (none of which were in June, near the end of breeding season), Easterla (1973*a*; 1973*b*) observed no evidence of pregnancy or parturition in *L. nivalis*, and only older juveniles were encountered. The evidence presented here suggests that at least some *L. nivalis* may give birth in BBNP.

Family Vespertilionidae
Myotis yumanensis (H. Allen)
Yuma Myotis

The Yuma myotis was first discovered within the current boundary of BBNP by Borell and Bryant (1942). This bat is a water surface forager (Findley, 1993) common to areas along the Rio Grande in BBNP (Borell and Bryant, 1942; Easterla, 1973*a*; 1973*b*). *Myotis yumanensis* was captured in the river floodplain habitat at localities characterized by open water (Cross Canyons on the Rio Grande, Menagerie Springs, Terlingua Abaja, and Terlingua Creek at the Rio Grande) more often than at localities crowded by vegetation and canyon walls (Glenn Springs). None were captured at sites in the sotol grasslands (Tables 3 and 4). *Myotis yumanensis* represented 2.3% of captures, yet was ranked as eleventh in relative abundance during this study (Tables 6 and 7).

It was the most common species captured where Terlingua Creek intersects the Rio Grande, which is a site having a large, open water source (Table 3). Of the 46 captured at five localities during this survey, 61% were taken at this site on two nights (22 May and 26 June 1998). An additional 24% were captured at the nearby Terlingua Abaja, an open water source that is located approximately two miles north of the Rio Grande on Terlingua Creek. These bats were often observed swarming over the Rio Grande before dusk and flying into the net as they snatched insects over the water's surface. Other species were captured at this site, yet *M. yumanensis* was the first to be obtained in the nets. These early captures may suggest the close proximity of roosts to this site, perhaps in

Figure 2. Seasonal occurrence of 10 species of bats in Texas. Black bars indicate previous records based on Schmidly (1991) and Yancey (1997). Grey bars indicate seasonal occurrence extensions based on capture data from Big Bend National Park (1996-1998). (Adapted from Schmidly, 1991).


Species
Mormoops megalophylla
Pregnant
Lactating
Juveniles
Leptonycteris nivalis
Pregnant
Myotis velifer
Pregnant
Lactating
Myotis yumanensis
Pregnant
Juveniles
Myotis californicus
Sub-adult
Pregnant
Lactating
Juveniles
Pipistrellus hesperus
Pregnant
Lactating
Juveniles
Eptesicus fuscus
Pregnant
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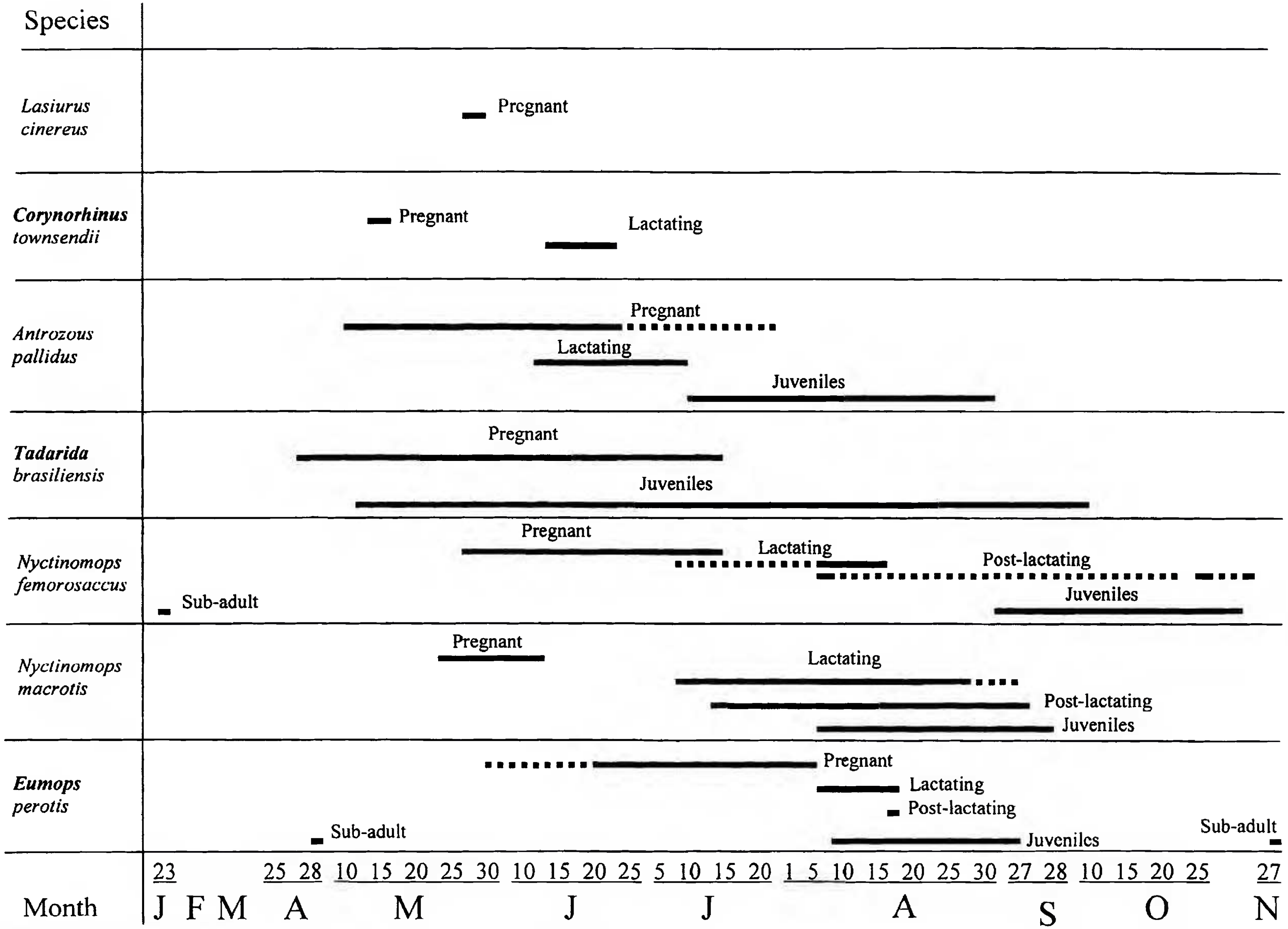

Figure 3. Summary of seasonal patterns of reproductive females and volant juveniles for 14 species of bats in Big Bend National Park, 1996-98 (after Easterla 1973a). Broad gaps in time between records are represented as dashed lines.

Table 8. Species list of Chiroptera in Big Bend National Park (after Big Bend Batural History Association, 2000).

Family Mormoopidae	
	Mormoops megalophylla (Ghost-faced Bat)
Family Phyllostomatidae	
	Leptonycteris nivalis (Mexican Long-nosed Bat)
Family Vespertilionidae	
	Myotis yumanensis (Yuma Myotis)
	Myotis velifer (Cave Myotis)
	Myotis thysanodes (Fringed Myotis)
	Myotis volans (Long-legged Myotis)
	Myotis californicus (California Myotis)
	Myotis ciliolabrum (Western Small-footed Myotis)
	Pipistrellus hesperus (Western Pipistrelle)
	Eptesicus fuscus (Big Brown Bat)
	Lasiurus borealis (Eastern Red Bat)
	Lasiurus cinereus (Hoary bat)
	Lasiurus xanthinus (Western Yellow Bat)
	Euderma maculatum (Spotted Bat)
	Corynorhinus townsendii (Townsend's Big-eared Bat)
	Antrozous pallidus (Pallid Bat)
Family Molossidae	
	Tadarida brasiliensis (Mexican Free-tailed Bat)
	Nyctinomops femorosaccus (Pocketed Free-tailed Bat)
	Nyctinomops macrotis (Big Free-tailed Bat)
	Eumops perotis (Western Mastiff Bat)

crevices of the adjacent Santa Elena Canyon or in nearby abandoned ruins.

Myotis yumanensis was netted each month from 1 March–26 July, and two individuals were netted 26 November 1997 (Fig. 6). The captures late in the year extend the known seasonal occurrence of this species in the state (Fig. 2) and suggest this bat winters in Big Bend.

Of the 42 individuals that were inspected for reproductive condition, 18 were females and 24 were males (Fig. 7). Only three pregnant females were identified, all of these were encountered in May. These findings agree with accounts that parturition in this species occurs in late May and early June (Schmidly, 1991). Twenty juveniles were captured on 26 June 1998 and 9 July 1997 collectively (Fig. 3), displaying a 1:1 sex ratio. Adult males that were checked for reproductive condition showed signs of testicular descent as early as March and as late as November.

Myotis velifer (J. A. Allen)
Cave Myotis

Taylor et al. (in litt.) were the first to encounter this species in BBNP. *Myotis velifer* is listed as an uncommon species in BBNP according to the National Park Service (Big Bend Natural History Association, 2000). In this investigation, 1.8% of all captures were *M. velifer* and it was the twelfth most frequently encountered species (Tables 6 and 7). Thirty-six *M. velifer* were captured in mist nets between 25 April and 17 June, and an additional individual was taken on 16 August 1996 (Fig. 8). The distribution of this bat in Texas was believed to vary seasonally, summering throughout the western two-thirds of the state and hibernating in caves in the central and north central portions of Texas (Schmidly, 1991), yet Yancey (1997) captured one individual in February at BBRSP. Although most *M. velifer* probably leave the area during the winter months, a few individuals may seek hibernacula in local caves or mines during winter months in BBNP.

Myotis velifer was found at five localities in all the vegetation zones we sampled, however, the occurrence of this species was more common in the shrub desert habitat in canyons where water sources were generally confined. On a single occasion it was taken over open water (Tables 3, 4 and 5). Sixty-one cave myotis were reported by Easterla (1973*a;* 1973*b*), and all were found in the lower elevation habitats except the sotol grasslands. Two individuals were encountered at two localities in the sotol grassland habitat in our study (Table 5).

Females outnumbered males two to one (Fig. 9). Four pregnant females were found May–June, and two lactating females were encountered in June (Fig. 3). One female carrying a nursing pup was captured on 17 June 1996 at Glenn Springs. Of the 11 males we obtained, nine were reproductively active (April–June). A single adult male was found in the river floodplain habitat, and two were taken at localities in the sotol grasslands (Tables 3 and 5). One volant juvenile female was captured 16 August 1996 (Fig. 3). Ten of the 25 individuals obtained at Glenn Springs were netted between 2045 h and 2145 h. These early captures suggest the presence of a nearby roost in the

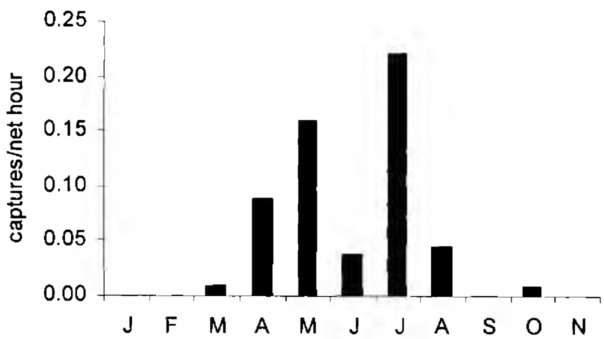

Figure 4. Seasonal distribution of *Mormoops megalophylla* (N=97) from capture data from 17 localities in BBNP, 1996-1998 (all years combined).

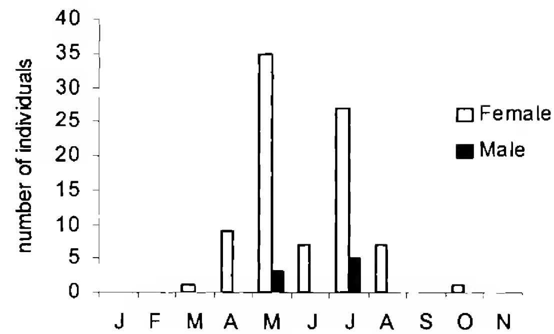

Figure 5. Seasonal distribution of male and female *Mormoops megalophylla* in BBNP, 1996-1998 (all years combined).

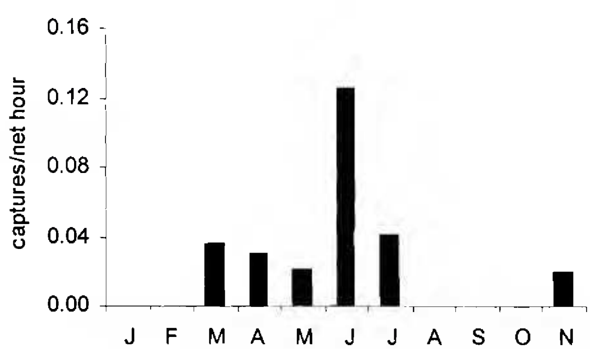

Figure 6. Seasonal distribution of *Myotis yumanensis* (N=46) from capture data from 17 localities in BBNP, 1996-1998 (all years combined).

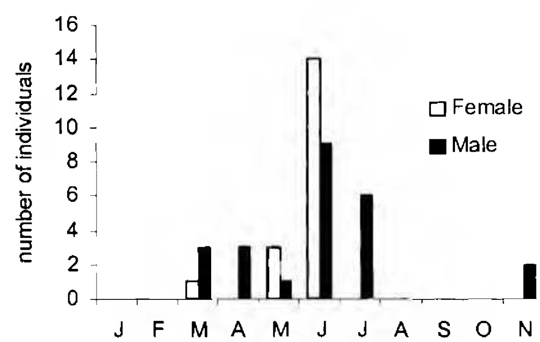

Figure 7. Seasonal distribution of male and female *Myotis yumanensis* in BBNP, 1996-1998 (all years combined).

area. All other *M. velifer* displayed activity throughout the night and were captured regularly between 2200 h and 0400 h.

This species appeared to have little difficulty maneuvering quickly during flight. *Myotis velifer* was frequently netted at Ernst Tinaja and Glenn Springs. Both localities contain narrow canyon corridors with restricted water sources, and Glenn Springs was overgrown with cattails, reeds, and other vegetation. An additional *M. velifer* was taken at Cattail Falls in the sotol grasslands. This locality consists of an upland pool and associated stream that is confined by a dense growth of trees on either side of the water source and a high rock wall on the southern edge, wherefrom runoff originating in the Chisos uplands drains (Table 5).

Myotis thysanodes (Miller)
Fringed Myotis

Borell and Bryant (1942) reported the first record of this species within the current boundary of BBNP. The National Park Service classifies this bat as uncommon in BBNP (Big Bend Natural History Association, 2000). *Myotis thysanodes* comprised 0.1% of all captures during this lowland study, ranking it among the lowest in relative abundance (Tables 6 and 7).

Two *M. thysanodes* were captured during this survey. A single adult male was obtained on 17 March 1996, and one adult female was taken on 23 May 1998 (Tables 4 and 5). Both *M. thysanodes* were captured at springs that were overgrown with vegetation. The single individual captured in March represents a seasonal occurrence record for this species in Texas (Fig. 2). The winter habits of this bat in Texas remain unknown.

Easterla (1973*a;* 1973*b*) captured 26 *M. thysanodes* with mist nets. He obtained only three at lowland sites located in the desert shrub habitat, although he observed many roosts for this species in the lowland regions of BBNP and adjacent sites in Mexico. These data suggest that *M. thysanodes* is rare in the lowland regions of BBNP, and it probably prefers to forage in the wooded Chisos Mountains in BBNP. Other authors have associated this species with mountainous regions in New Mexico, yet it was occasionally encountered at lower elevations (Barbour and Davis, 1969). The association of this species with montane habitats may explain the low abundance of this bat during this study.

Myotis californicus (Audubon and Bachman)
California Myotis

Borell and Bryant (1942) were first to capture this species within the current boundary of BBNP. The National Park Service considers this bat an uncommon resident (Big Bend Natural History Association, 2000). This bat comprised 1.5% of all captures (ranking tenth in order of overall captures), yet it ranked eighth in order of relative abundance due to the relatively high number of nights this species was encountered (Tables 6 and 7). Rarely more than one was captured on a given night, yet *M. californicus* was encountered at over half the localities surveyed in this study. Easterla (1973*a;* 1973*b*) also captured this species in relatively low numbers at many localities.

Myotis californicus is one of the smallest species of *Myotis*, occurring in Texas only in the Trans-Pecos region (Schmidly, 1991). Thirty individuals were captured at 10 lowland sites (Tables 3, 4 and 5), apparently showing no preference for a given vegetation zone. This bat was taken over open water, overgrown springs, and in narrow canyons. All were captured 17 March–17 August except one sub adult male captured 23 January (Fig. 10). *Myotis californicus* appears to be a year-round resident of the Trans-Pecos, as there are records indicating that it stays fairly active throughout the winter months (Young and Scudday, 1975; Schmidly, 1991). This species is one of the few we characterize herein as a "water source generalist," as it was found over confined and open water sources in a variety of habitats.

Females outnumbered males 2:1 (Fig. 11). Four pregnant females were captured from 27 April to 23 May, and four lactating females were encountered between 9 June and 10 July (Fig. 3). Two juveniles, one male and one female, were encountered on 9 July and 16 August respectively. Males with descended testes were found in April, July, August, and January. Dorsal pelage coloration differed from reddish to brownish, although most were reddish.

Pipistrellus hesperus (H. Allen)
Western Pipistrelle

Bailey (1905) reported the first record of this species within the current boundary of BBNP. *Pipistrellus hesperus* is considered to be common in BBNP by the National Park Service (Big Bend Natural History Association, 2000). This bat is among the most common bats inhabiting the lowland southwestern desert regions of the United States (Barbour and Davis, 1969). *Pipistrellus hesperus* accounted for 8.5% of captures, ranked third in relative abundance, and was among the most widely distributed species in this investigation along with *Antrozous pallidus* and *Tadarida brasiliensis* (Tables 6 and 7). One hundred sixty-nine individuals were captured at 11 sites in all three vegetation associations that were sampled, displaying widespread usage of the lowlands (Tables 3, 4 and 5). This bat was common in open riparian areas, shallow and deep canyons, and springs and ponds that were crowded with vegetation. *Pipistrellus hesperus* was among the first bats to emerge in the evening and was often observed over water sources before dusk.

Captures of *P. hesperus* took place 16 March–27 November (Fig. 12), yet it was absent from our nets during the winter months. At the nearby BBRSP, Yancey (1997) found this species monthly throughout the year with the exception of January. *Pipistrellus hesperus* likely occurs in BBNP during winter months as well, seeking shelter in rock crevices, under rocks, or in man-made structures where it normally roosts (Schmidly, 1991). Consequently, the absence of this species during winter in this survey is likely due to the lack of winter visits to localities where *P. hesperus*

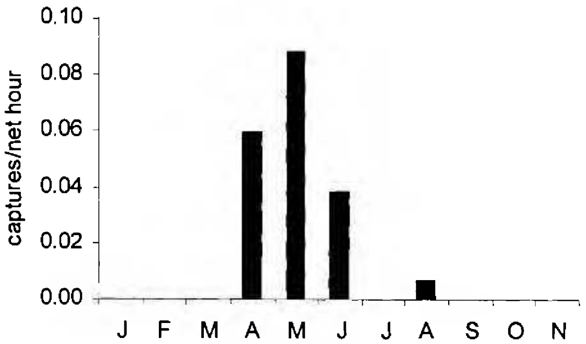

Figure 8. Seasonal distribution of *Myotis velifer* (N=36) from capture data from 17 localities in BBNP, 1996-1998 (all years combined).

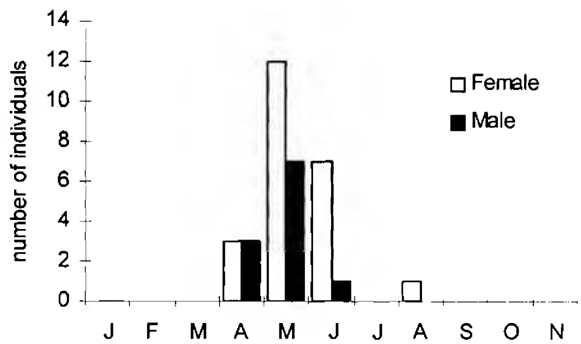

Figure 9. Seasonal distribution of male and female *Myotis velifer* in BBNP, 1996-1998 (all years combined).

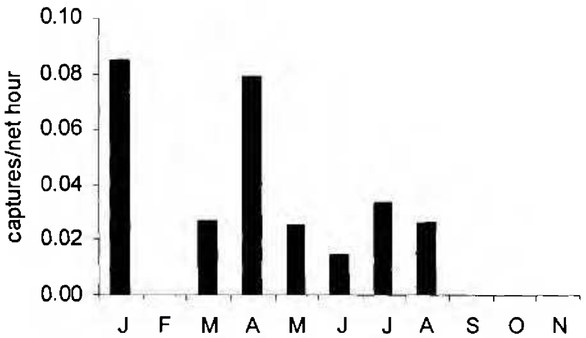

Figure 10. Seasonal distribution of *Myotis californicus* (N=30) from capture data from 17 localities in BBNP, 1996-1998 (all years combined).

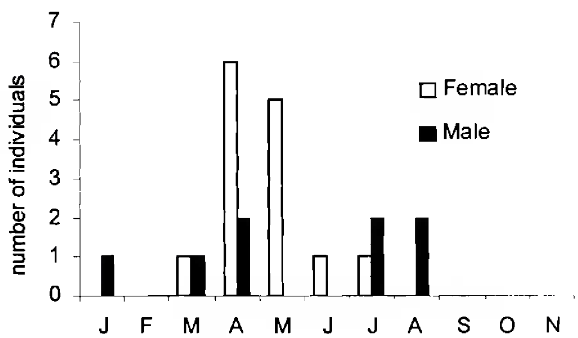

Figure 11. Seasonal distribution of male and female *Myotis californicus* in BBNP, 1996-1998 (all years combined).

was found in abundance in spring and summer, such as Glenn Springs and Ernst Tinaja.

Males and females were obtained in equal proportions, yet only half as many males were taken from mist nets compared to females in June and July (Fig. 13). Pregnant females were netted 25 April–14 July, while lactating individuals were found 11 June–10 July. A single post-lactating female was captured on 25 July (Fig. 3). This correlates closely to Easterla's (1973*a;* 1973*b*) encounters of lactating females 12 June–9 July, with an additional post-lactating individual recorded on 21 July. Easterla (1973*a;* 1973*b*) captured only two pregnant *P. hesperus* on 12 and 18 June. Bailey (1905) reported pregnancy in this species as early as May in BBNP. A very high proportion of females examined in this survey during May and June were pregnant (16 out of 21 in May and 18 out of 22 in June). Females captured in August showed no signs of reproduction. Juveniles were encountered 26 June–29 August (Fig. 3), although Easterla (1973*a;* 1973*b*) noted young beginning 18 June. Testes examined in males were descended 16 March–4 September.

Eptesicus fuscus (Palisot de Beauvois)
Big Brown Bat

This species was first reported from within the current boundary of BBNP by Bailey (1905). The park lists this species as uncommon, yet evenly distributed throughout the park (Big Bend Natural History Association, 2000). *Eptesicus fuscus* comprised 1.5% of all captures and ranked tenth in relative abundance (Tables 6 and 7). This bat appears to be a habitat generalist in BBNP, as we found it evenly distributed among the lowland sites. Twenty-nine individuals were obtained at six sites in three vegetation zones (Tables 3, 4 and 5). Easterla (1973*a;* 1973*b*) found relatively low numbers of this species in every plant habitat in BBNP, with the exception of the sotol grasslands. Yancey (1997) reported *E. fuscus* as commonly occurring in BBRSP, and it was the fourth most frequently netted bat during his investigation. This bat is a year-round resident in Texas (Schmidly, 1991), yet it was only encountered 26 April–11 October in this survey with 69% of all captures of this species occurring in May (Fig. 14). This species was among the late fliers, and commonly entered the mist nets well after dusk. It is not yet clear if this bat overwinters in BBNP, however, an abundance of suitable hibernacula exist in the park. This bat has been observed roosting in a variety of retreats including caves, mines, buildings, rock crevices, and storm sewers (Schmidly, 1991).

Females were distributed across a greater number of sites in the lowlands than males, outnumbering males two to one. Nine of the 11 males identified were captured at Glenn Springs, corroborating Easterla's (1973*a;* 1973*b*) account of altitudinal segregation of the sexes in the park during summer, when females are more often encountered in the lowlands where conditions for giving birth are presumably more favorable. The annual distribution of males and females is given in Figure 15. Of the 18 females examined, 13 were pregnant 26 April–24 May (Fig. 3). No lactating females or young were discovered, however, this may be explained by the relatively low numbers in which they were encountered during the course of this study. It should be noted that of the 68 *E. fuscus* captured by Easterla (1973*a;* 1973*b*), no pregnant females and only one juvenile were recorded. Evidence of sexual activity in males during this study was noted 26 April–9 July.

Lasiurus cinereus (Palisot de Beauvois)
Hoary Bat

This species was first discovered within the current boundary of BBNP by Borell and Bryant (1942). The status of this solitary, tree-roosting species is uncommon in BBNP according to the National Park Service (Big Bend Natural History Association, 2000). Although the species comprised only 1.2% of all captures, *L. cinereus* ranked ninth in relative abundance during 94 visits to capture sites in this survey (Tables 6 and 7). Twenty-five *L. cinereus* were encountered at six sites in the river floodplain and shrub desert habitats (Tables 3 and 4) between 18 March and 11 October (Fig. 16). Easterla (1973*a;* 1973*b*) captured 14 *L. cinereus* park-wide, but only three of these were captured in the lowlands. Apparently this bat utilizes the lowland habitats in Big Bend to a greater degree than originally thought.

Findley and Jones (1964) summarized the seasonal distribution of this transcontinentally distributed, migratory species. According to the findings they presented, spring migration is segregated, with females moving northward to have their young in the northern, eastern, and central United States prior to the migration of males, who generally occupy habitats in the montane regions of the western United States during summer months. August marks their return to wintering grounds, and little evidence is available showing sexual segregation during this time, yet distinct migratory waves have been noted August–October. Past accounts from BBNP report the presence of males only in the summer months, and mostly at the higher elevations (Easterla, 1973*a;* 1973*b*). We encountered one adult female showing no signs of pregnancy or parturition on 16 August which was possibly an early migrant. Four additional females were found 18 March and 10 and 26 May (Figure 17). These bats were presumably passing through on their migration northward. Prior to our investigation, females were not taken in the park before 29 March (Easterla, 1973*a;* 1973*b*). With the exception of the female taken in August, these findings corroborate previous reports of the reduced abundance of females during summer months in BBNP.

Seventeen males were netted in April, May, August, and September, but none were recorded June through July (Fig. 17). Perhaps males are concentrated in the higher elevations of the Chisos at this time. In Big Bend, *Lasiurus cinereus* is evidently a rare summer resident with populations increasing during spring and fall migration.

During this investigation, no juveniles were recorded. Fifteen of the 17 males examined exhibited

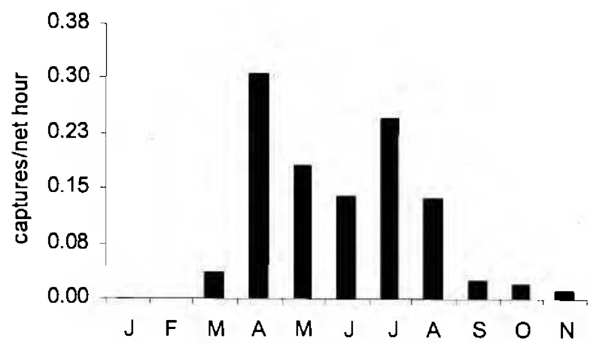

Figure 12. Seasonal distribution of *Pipistrellus hesperus* (N=169) from capture data from 17 localities in BBNP, 1996-1998 (all years combined).

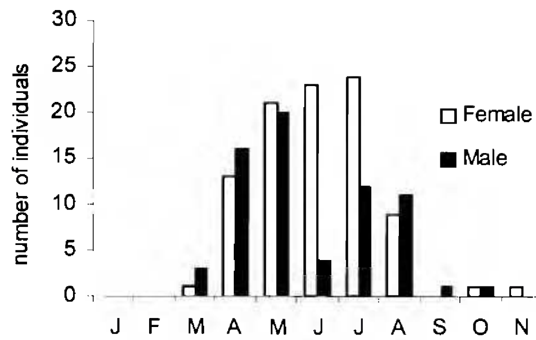

Figure 13. Seasonal distribution of male and female *Pipistrellus hesperus* in BBNP, 1996-1998 (all years combined).

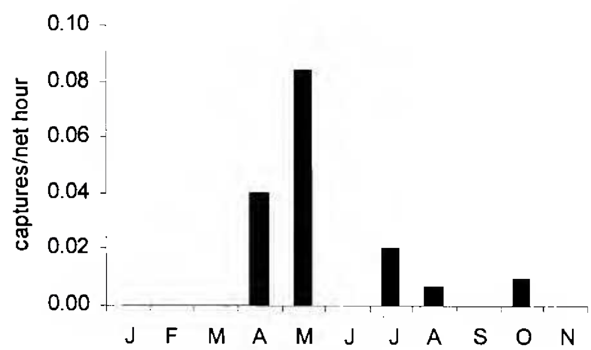

Figure 14. Seasonal distribution of *Eptesicus fuscus* (N=29) from capture data from 17 localities in BBNP, 1996-1998 (all years combined).

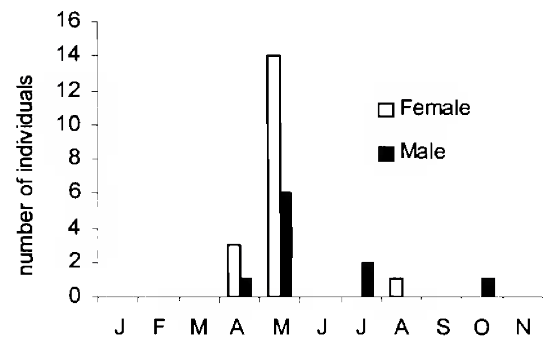

Figure 15. Seasonal distribution of male and female *Eptesicus fuscus* in BBNP, 1996-1998 (all years combined).

descended testes 25 April–27 September. *Lasiurus cinereus* was most common within an hour after sunset and just before dawn. A general lull in their activity over water was exhibited by only a few captures during the late evening and early morning hours.

Lasiurus xanthinus (Thomas)
Western Yellow Bat

This bat was first encountered in Big Bend in 1996 (Higginbotham et al., 1999). The National Park Service lists this bat as a rare species (Big Bend Natural History Association, 2000). *Lasiurus xanthinus* ranked fourteenth in relative abundance during 94 netting nights, comprising 0.2% of all captures and was more commonly encountered than some species of bats considered to be established residents in BBNP (Tables 6 and 7). The western yellow bats captured during this investigation represent the first reports of this species in BBNP, and the state of Texas. Additional accounts of *L. xanthinus* from Texas have recently been reported from the Davis Mountains State Park, Jeff Davis County (Jones et al., 1999), the Black Gap Wildlife Management Area, Brewster County (Bradley et al., 1999), and within the city limits of Del Rio, Val Verde County (Weyandt et al., 2001). These recent reports provide evidence that the western yellow bat is expanding its range northward.

Three adult males and one adult female were captured 4 September–24 November 1996–1998 at Menagerie Springs. This locality is a spring-fed pool in the river floodplain habitat (Table 3). Despite 28 nights of netting at this site, predominately during the summer months, the western yellow bat was only encountered in the fall during this study. However, since the completion of this wurvey, four additional males have been encountered at Menagerie Springs, and two of these were obtained in June 1999. Two of the three males obtained during the survey reported herein displayed testicular descent on 12 October and 14 September. The single adult female taken on 24 November exhibited no signs of reproductive activity.

Lasiurus xanthinus has recently been observed roosting in giant dagger yucca (*Yucca carnerosana*) in BBNP, a roost type not previously associated with this tree-roosting genus (Higginbotham et al., 2000). The location of an isolated population of giant dagger yucca in relatively close proximity to the site where all *L. xanthinus* have been captured in Big Bend may not be coincidental. Yet, an additional record of *L. xanthinus* from the Trans-Pecos (Jeff Davis County) was found in upland riparian woodland (Jones et al., 1999) and represents quite a different habitat than that observed for this species in BBNP. The presence of females and reproductive males throughout various seasons in the Trans-Pecos substantiate a northward range expansion of this species into Texas.

Euderma maculatum (H. Allen)
Spotted Bat

First encountered in Big Bend in 1969 (Easterla, 1970), this elusive bat is among the least encountered and poorly understood species of bats in BBNP, and probably the United States (Schmidly, 1991). The National Park Service considers this species to be rare in BBNP (Big Bend Natural History Association, 2000). In this survey, only 0.1% of all captures were *E. maculatum*, ranking it among the least abundant species of bats along with *L. nivalis* and *M. thysanodes* (Tables 6 and 7). The Big Bend region represents the southernmost and easternmost borders of this bat's range in the United States. In other parts of its range, it has been netted in a wide range of elevations and habitats from desert scrub to montane coniferous forests (Watkins, 1977). The distribution of *E. maculatum* is spread across the western United States, British Columbia and northern Mexico, yet encounters are few and they tend to be locally abundant in isolated areas (Easterla, 1973a, 1973b; Woodsworth et al., 1981; Leonard and Fenton, 1983; Fenton et al., 1987). The low encounter rate of this species throughout its range is reflected by the few specimens recorded in the literature before Easterla's (1973*a;* 1973*b*) work in BBNP, as he encountered more individuals at a single site than had been previously recorded elsewhere.

Euderma maculatum is difficult to capture using mist nets and its presence in a given area may be best investigated by acoustical survey methods (Fenton et al., 1987; O'Farrell, 1997). We captured two adult males on 9 June 1997 and 21 May 1998 at Mariscal Canyon on the Rio Grande and Menagerie Springs, respectively (Table 3), although the distinctive, audible echolocation calls of this bat were heard frequently throughout much of BBNP during this work. An unrevealed site sampled in BBNP by Easterla (1973*a;* 1973*b*) yielded 51 of the 54 *E. maculatum* captured by him from 1968–71. X-site, as named by Easterla, produced the most captures of this species at any one location.

The capture of a single *E. maculatum* from Menagerie Springs, which was a reliable water-source during this investigation, may be explained by the dry conditions experienced in the region during 1998. We observed fewer water sources in the lowland regions during this time, and many of our reliable netting localities held markedly diminished water levels. This dry period effectively resulted in fewer water sources to choose from. Bats not normally utilizing the water source at Menagerie Springs may have been forced to seek it out as an alternative drinking site during this dry period. This is supported by the lack of captures of *E. maculatum* at this spring despite 28 visits to this site throughout this survey. The spotted bat is known to roost in rock crevices located in high cliff walls (Easterla, 1970; Leonard and Fenton, 1983), which is characteristic of those observed in Mariscal Canyon on the Rio Grande, the only other site where this species was found during this study.

Evidently this bat emerges late in the evening to drink and forage. Both individuals discussed here were captured after midnight standard time. This is concurrent with Easterla's (1973*a;* 1973*b*) reports that most spotted bats he encountered in BBNP were taken after midnight. Both males we report exhibited descended testes. The winter habits of this species are not well understood in BBNP, as no winter records exist.

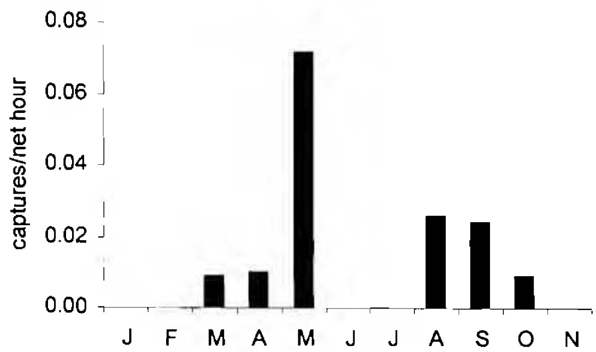

Figure 16. Seasonal distribution of *Lasiurus cinereus* (N=25) from capture data from 17 localities in BBNP, 1996-1998 (all years combined).

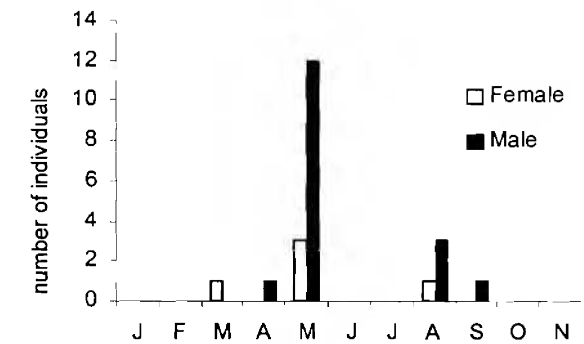

Figure 17. Seasonal distribution of male and female *Lasiurius cinereus* in BBNP, 1996-1998 (all years combined).

Corynorhinus townsendii (Cooper)
Townsend's Big-eared Bat

Borell and Bryant (1942) first recorded this species in Big Bend in 1937. The National Park Service reports this bat as uncommon in BBNP (Big Bend Natural History Association, 2000). *Corynorhinus townsendii* was rarely encountered in mist nets during this survey, ranked thirteenth in relative abundance, and comprised 0.9% of all captures (Tables 6 and 7).

This species commonly hibernates in caves and mines and is an established year-round resident in Texas (Schmidly, 1991). It has been captured in a variety of habitats ranging from evergreen forests to desert shrub-grasslands (Kunz and Martin, 1982), yet it was encountered in this study only in rocky canyons. In BBRSP, *C. townsendii* was associated with springs and streams in riparian woodland habitat and was also found to be relatively uncommon (Yancey, 1997).

Seventeen individuals were taken at three sites in the shrub desert and sotol grassland habitats (Tables 4 and 5), although the majority of Easterla's (1973*a;* 1973*b*) encounters of *C. townsendii* occurred in the uplands. The occurrence of this species in BBNP may be somewhat limited by habitat type as evidenced by the absence of mist net captures from the river floodplain region and the few captures within the intermediate elevations during Easterla's (1973*a;* 1973*b*) study and this one.

All individuals were captured 16 March–21 June (Fig. 18), and most were obtained well after sunset. Our encounters of *C. townsendii* were limited to spring and early summer, and may reflect fewer visits to capture sites during fall and winter months where *C. townsendii* was taken during other sampling periods. Seven males were captured 16 March–21 June (Fig. 19). Males were obtained two months prior to females, and six of the seven males taken showed signs of testicular descent. Between 13 May and 21 June, 10 females were obtained, two of which were pregnant on 13 May 1996 at Fresno Creek. Five lactating females were encountered 13 June and 21 June (Fig. 3). No juveniles were encountered.

Antrozous pallidus (Le Conte)
Pallid Bat

Bailey (1905) first discovered this bat within the present boundary of BBNP. The National Park Service lists this species as common in BBNP (Big Bend Natural History Association, 2000). The pallid bat is among the most common and widespread species of bats in the lower elevations of the desert southwestern United States (Barbour and Davis, 1969). According to our results, *A. pallidus* was one of the most common bats in BBNP, ranking second to *Tadarida brasiliensis* in relative abundance, and ranking third in capture frequency during this investigation (Tables 6 and 7). Two hundred and forty-seven individuals were netted at 14 sites in the three plant habitats that were

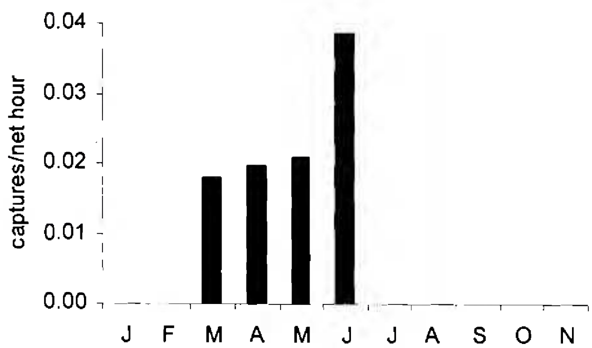

Figure 18. Seasonal distribution of *Corynorhinus townsendii* (N=17) from capture data from 17 localities in BBNP, 1996-1998 (all years combined).

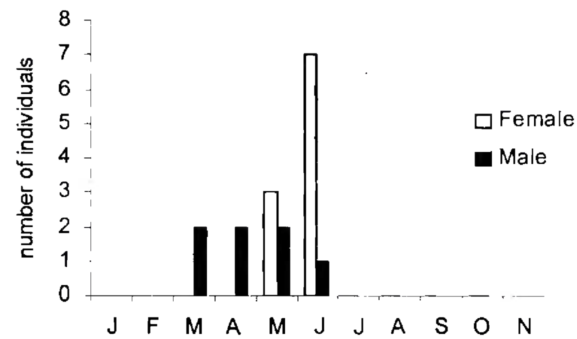

Figure 19. Seasonal distribution of male and female *Corynorhinus townsendii* in BBNP, 1996-1998 (all years combined).

surveyed (Tables 3, 4 and 5). Easterla (1973*a;* 1973*b*) found this species to be the most common bat in BBNP during his study as it occurred park-wide across all plant associations. Recently in BBRSP however, it was reported as the fifth most frequently netted bat (Yancey, 1997).

Capture dates ranged from17 March through 26 November, with 43% of these captures occurring in April and May, and few captures in fall and early spring (Fig. 20). Prior to this work, *A. pallidus* had not been reported from Texas later than October (Fig. 2). *Antrozous pallidus* is thought to be a year-round resident in other parts of its range and it is thought to hibernate during winter (Barbour and Davis, 1969; Hermanson and O'Shea, 1983). In Texas, no winter records exist for this species, yet it is thought to remain year-round throughout much of its summer range and is not known to undergo long migrations (Schmidly, 1991). Although the winter habits of this species remain unclear in the Big Bend region, it is likely a hibernating winter resident.

We typically encountered pallid bats after dusk and thereafter throughout the night. One night roost was found in the open garage of a residence near Rio Grande Village (Fig. 1). This roost apparently was used frequently, as urine stains, guano deposits, and insect wings had accumulated on the floor of the garage.

The sex ratio was approximately 1:1 (Fig. 21). Fourty-eight females were pregnant between 25 April and 25 July (Fig. 3). Yancey (1997) obtained only five pregnant females in BBRSP. Although Easterla (*1973a; 1973b*) found *A. pallidus* higher in relative abundance during his study in comparison to ours, he encountered no pregnant females. One pregnant female captured by Bailey (1905) on 28 May near Boquillas, Coahuilla, Mexico led Easterla to postulate that parturition in *A. pallidus* took place in BBNP earlier than his summer investigations, perhaps only in May (Easterla, 1973*a;* 1973*b*). The data we present confirm that parturition in this species in BBNP takes place well into the summer months. Lactating females were examined 11 June –25 July. A single post-lactating female was netted on 25 July, and juveniles were encountered 10 July–1 September (Fig. 3). Males with descended testes were encountered 17 March–26 November.

Family Molossidae
Tadarida brasiliensis (Geoffroy Saint-Hilaire)
Mexican Free-tailed Bat

Bailey (1905) was the first to encounter this species in BBNP. *Tadarida brasiliensis* is considered to be common in BBNP by the National Park Service (Big Bend Natural History Association, 2000). This species has been described as the most common bat in lowland areas of the Trans-Pecos (Schmidly, 1977). *Tadarida brasiliensis* was the most frequently encountered bat during this survey, ranking first in relative abundance and comprising 42.5% of all captures (Tables 6 and 7), yet previous studies in BBNP have classified *T. brasiliensis* as third in relative abundance

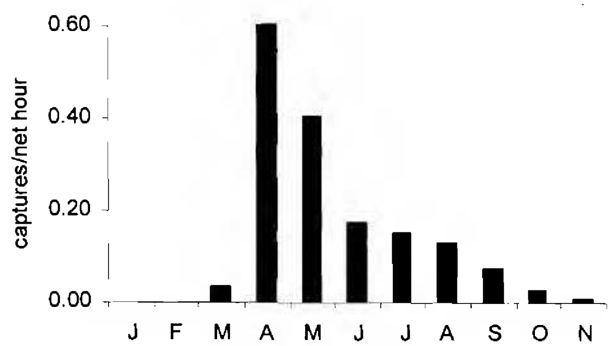

Figure 20. Seasonal distribution of *Antrozous pallidus* (N=247) from capture data from 17 localities in BBNP, 1996-1998 (all years combined).

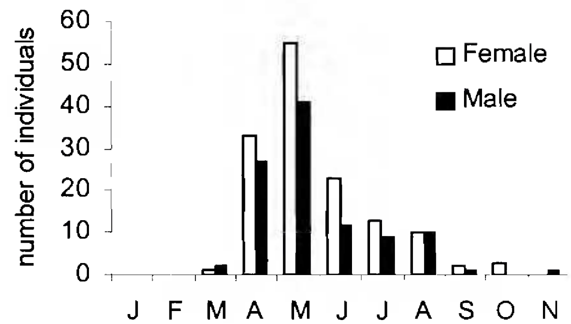

Figure 21. Seasonal distribution of male and female *Antrozous pallidus* in BBNP, 1996-1998 (all

among species of bats (Easterla, 1973*a;* 1973*b*). Recently, Mexican free-tailed bats were found to be relatively less abundant at BBRSP, where it was the third most frequently encountered species of bat (Yancey, 1997). Our investigations produced eight hundred and forty captures of this bat at 12 of the 17 localities we sampled in all three lowland plant habitats. *Tadarida brasiliensis* was more common in open riparian areas along the river floodplain, but it was also taken in both deep and shallow canyons and localities with dense vegetation (Tables 3, 4, and 5).

Tadarida brasiliensis mexicana, the subspecies occurring in BBNP, is known to undergo extensive migrations between its winter and summer ranges (Schmidly, 1991). This species is widespread throughout Texas and most of the southern United States during the summer months, however, large numbers migrate to Mexico for the winter, traveling at reported distances of up to 1,840 kilometers (Wilkins, 1989). In many parts of its summer range including Texas, millions of *T. brasiliensis* may roost in large maternity colonies in a single cave, yet a host of other roost types have been reported including culverts, bridges, buildings, rock crevices, and cliff swallow nests (Wilkins, 1989; Schmidly, 1991).

Winter records of *T. brasiliensis mexicana* from Texas are sparse, yet populations have been documented to occur year-round in Texas based on isolated records (personal observation; Schmidly, 1991). This study produced no winter captures of *T. brasiliensis*, though it was encountered 15 March–27 November (Fig. 22). The early spring and late fall captures of Mexican free-tailed bats we recorded may suggest that some individuals likely winter in BBNP, as BBNP occurs along the northern boundary of the winter range of some adjacent populations (Wilkins, 1989).

The numbers of *T. brasiliensis* in the Trans-Pecos fluctuate seasonally, with migratory individuals arriving in March and departing in November (Schmidly, 1977). A biannual increase in captures of this species during the course of this work is depicted in Fig. 22. The timing of these influxes coincides with the expected migration periods this species displays, and the increase in captures at BBNP during these periods are likely a result of migratory waves passing through the region. These data indicate that most *T. brasiliensis* arrive or pass through BBNP in March, with a southern wave of fall migration taking place September–November. Summer residents may begin to leave the area before fall migrants, located to the north of BBNP, begin passing through, as demonstrated by the dramatic drop in captures of *T. brasiliensis* in August despite heavy sampling during this time at localities frequented by this species (Fig. 22). The high relative abundance (Table 7) of *T. brasiliensis* during this study is likely skewed towards migrants, as it was taken from nets during migratory periods in higher proportions than were summer residents at times other than peak migration periods. The increased activity observed during May, June and July (Fig. 22) is not significantly influenced by the presence of juveniles, since only seven were encountered during these months. The second increase in activity (September–November) was likewise not influenced by young, as only 10 young of 258 individuals were recorded during October and November across the entire sampling period.

Constantine (1967) reports that the arrival of males typically precedes that of females during spring migration, however we observed both males and females in March in BBNP, yet in unequal proportions (Fig. 23). The number of males encountered during a given month was greater than females (excluding November), and males slightly outnumbered females 2:1 overall. Easterla (1973*a*; 1973*b*) proposed the segregation of reproductively active females from other *T. brasiliensis* during the summer months. Easterla suggested that only males and a few non-reproductive females occur in Big Bend during this time because he encountered mostly males, a few non-reproductive females, and no juveniles in the park during summer months. The few pregnant females encountered by Easterla were considered as late migrants passing through to give birth elsewhere since he did not encounter juveniles before 9 September, nor did he capture any lactating and post-lactating individuals (Easterla, 1973*a*; 1973*b*). We captured only six noticeably pregnant females during June and July during this study. Additionally, the low capture rate of pregnant females in the lowlands during mid-summer may be due to earlier parturition, as suggested by the capture of pregnant individuals 25 April–17 July, and the capture of 17 young 25 May–26 June during this study (Fig. 3). In contrast, Yancey (1997) obtained only males at BBRSP 6 June–July. Although lactating and post-lactating individuals were not observed during our investigation, the encounter of pregnant individuals and young suggest that some females do remain in the lowland regions to give birth in BBNP.

Many *T. brasiliensis* were not checked for age or reproductive condition because of the large numbers encountered in a short period of time during migratory waves. Consequently, the number of reproductively active females and juveniles recorded may not have been accurately reflected in these data. Although the segregation of reproductive females from males in BBNP during summer remains unclear, it should be noted that only 32 females were taken from four sites during June and July while 193 males were found at only six localities during the same period of time. Hence, although males outnumbered females

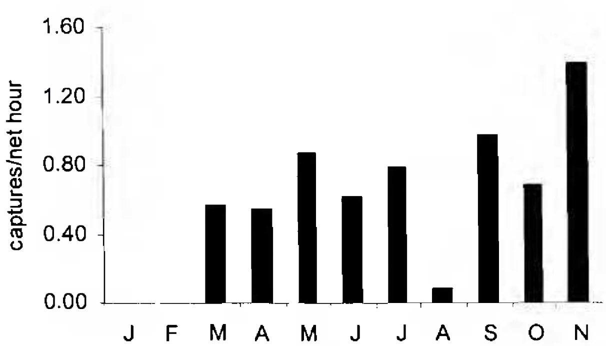

Figure 22. Seasonal distribution of *Tadarida brasiliensis* (N=840) from capture data from 17 localities in BBNP, 1996-1998 (all years combined).

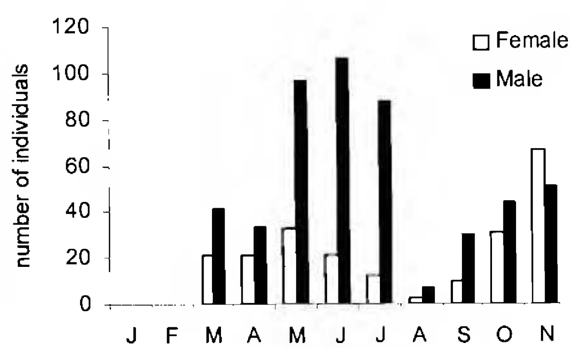

Figure 23. Seasonal distribution of male and female *Tadarida brasiliensis* in BBNP, 1996-1998 (all years combined).

overall 2:1 (Fig. 23), each sex appeared to be distributed relatively evenly among sites.

Reproductive data reported for *T. brasiliensis* from this study is incomplete. Seven hundred and fourteen individuals were sexed out of the 840 individuals captured, and many of these were not checked for reproductive condition due to the large numbers encountered during peak migration periods coupled with limited processing time.

Nyctinomops femorosaccus (Merriam)
Pocketed Free-tailed Bat

Easterla (1968) was the first to report this species in BBNP. The status of this species in BBNP is considered to be uncommon according to the National Park Service (Big Bend Natural History Association, 2000). Our work found *N. femorosaccus* second in percentage of all captures (Table 6), yet fourth in relative abundance (Table 7). These numbers are unusually high for a species considered as locally uncommon. Relative abundance may be a more accurate representation of the population status of this species in the BBNP bat community, since a sampling bias toward a particular site where this species was regularly found in high abundance (Menagerie Springs; Table 3) likely elevated the overall capture rate of *N. femorosaccus*.

The distribution of this bat in Texas is limited, having only been recorded from the Big Bend region (Schmidly, 1991; Higginbotham et al., in press). We captured 259 *N. femorosaccus* at five sites within the river floodplain habitat (Table 3). Most *N. femorosaccus* recorded during this survey were obtained from Menagerie Springs, the heavily sampled site on Tornillo Creek. The distribution of this bat in BBNP appears to be limited to the lower elevations, as it has only been recorded there (Easterla, 1973*a*, 1973*b*; this study).

Nyctinomops femorosaccus typically roosts in rock crevices (Kumirai and Jones, 1990) that are characteristic of the canyons scattered throughout the lowland regions of BBNP. This species was observed in several rock crevice roosts located high in canyon walls at a single locality in the river floodplain region during the spring, fall, and winter months of this study (no summer visits were made to the roost site). Positive identification of roosting *N. femorosaccus* was facilitated by the use of a small infrared camera mounted on an extendible fifty-foot pole. Roost emergence counts were highest in early fall, with a drastic decline from September to October in 1997 (over 700 exits to only 10 exits, respectively).

Audible social activity heard from these roosts in January and February 1998, as well as mist net captures in the creek bed beneath the roosts during November 1997, and January and February 1998, indicate the year-round presence of this species in BBNP. The majority of *N. femorosaccus* probably migrate out of the area during the winter months, as declines in roost emergence counts (12 individuals or less from November through February) and capture data obtained during this time suggest (Fig. 24).

Nyctinomops femorosaccus was captured 23 January–27 November (Fig. 24). These data significantly extend the previously known seasonal occurrence of this species in Texas (Fig. 2). Prior to this investigation, accounts of this species from the Big Bend region indicated their presence in Texas June–August (Easterla, 1973*a;* 1973*b*; Schmidly, 1991). Figure 24 illustrates two peaks in seasonal activity, one in mid-summer and a second in the fall. The second peak raises questions about the fall activity of this species. The onset of juvenile activity during late summer and early fall (Fig. 25) does contribute some to the fall peak of activity in *N. femorosaccus* observed overall, but does not explain it entirely. The low encounter rate of this species experienced during winter netting efforts supports the hypothesis that most *N. femorosaccus* probably do leave the area during this time. Although netting effort during the month of September was reduced, an annual peak of activity is observed. Moreover, an increase in captures was recorded during November, suggesting increased numbers of *N. femorosaccus* in the Big Bend region (or perhaps increased activity levels) during this time. Migratory activity may explain this trend, yet little data are available on migration in this species. Winter records from other parts of the species' range in the extreme desert southwestern United States suggest this species is a permanent resident in these areas (Barbour and Davis, 1969). The peak in activity observed during fall in this investigation may reflect migratory waves traveling southward through the Big Bend region during this time. However, BBNP lies along the northernmost range of *N. femorosaccus* in Texas, and represents the eastern border of their range in the United States (Kumirai and Jones, 1990). The known northern distributional limits of *N. femorosaccus* in Texas and New Mexico extend into extreme southwestern New Mexico, extreme southeastern New Mexico and the Big Bend region of Texas (Kumirai and Jones, 1990). Although a recent survey (Higginbotham et al., in press) found evidence of *N. femorosaccus* in Presidio County, no other records for this species in the state of Texas exist outside of southern Brewster County (Schmidly, 1991). However, *N. femorosaccus* has been reported from Carlsbad Caverns in southeastern New Mexico, about 350 kilometers north of BBNP (Barbour and Davis, 1969). The population in Carlsbad Caverns may pass through the Big Bend region during migratory periods while in route to warmer wintering grounds in Mexico, although this is speculative. Reasons for this observed increase in activity exhibited by *N. femorosaccus* during fall in BBNP remain uncertain and more data are needed to explain this trend.

Females outnumbered males 2:1, and females were captured in higher numbers during each month with the exception of February and March (Fig. 26). Forty-one pregnant females were examined 26 May–4 August. Fourteen lactating and seven post-lactating individuals were observed 20 June–17 August and 4 August–25 October, respectively (Fig. 3). Thirty-nine juveniles were observed 29 August–27 November, and one sub-adult individual was captured on 23 January (Fig.3). Testicular descent was noticed in five males captured 14 July–4 August.

Nyctinomops femorosaccus was encountered in nets beginning 45 minutes after sunset, a trend observed by other researchers of this species (Gould, 1961). However, emergences from roosts occupied by pocketed free-tailed bats were observed prior to sunset during the fall of 1997 and the spring of 1998.

The high capture rate of 237 bats of this species at Menagerie Springs and 17 at Terlingua Abaja (Table 3), with few captures at other study sites may imply a preference in this species towards the surface structure of available water sources. This bat may be considered as an "open water specialist," based on its encounter rate at open water sources characteristic of the Rio Grande and its tributaries within BBNP. Diurnal social chattering characteristic of *N. femorosaccus* (Barbour and Davis, 1969; Easterla, 1973*a*, 1973*b*; Kumirai and Jones, 1990) was heard from several vertical rock crevices lining the walls of Mariscal Canyon

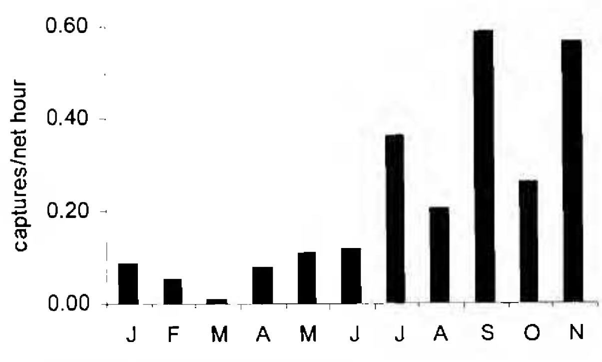

Figure 24. Seasonal distribution of *Nyctinomops femorosaccus* (N=259) from capture data from 17 localities in BBNP, 1996-1998 (all years combined).

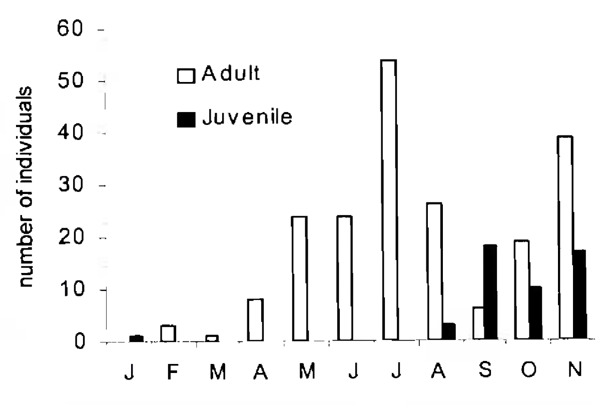

Figure 25. Seasonal distribution of juvenile and adult *Nyctinomops femorosaccus* in BBNP, 1996-1998 (all years combined).

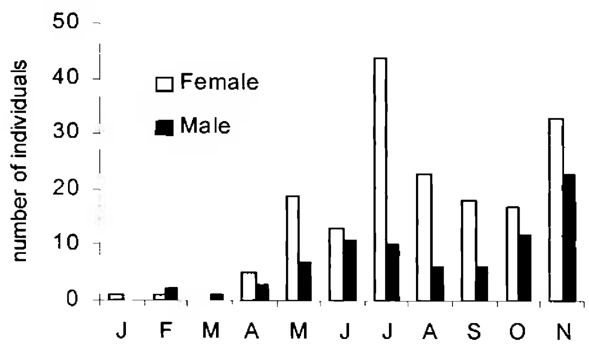

Figure 26. Seasonal distribution of male and female *Nyctinomops femorosaccus* in BBNP, 1996-1998 (all years combined).

during a survey of this region of the Rio Grande corridor in June 1997.

In an effort to assess the population status of *N. femorosaccus* in BBNP, 191 of the 259 individuals encountered were marked with wing bands. Two of these were recaptured at Menagerie Springs, the original capture locality. Three more banded individuals were observed in the aforementioned rock crevice roosts identified along Tornillo Creek, yet specific band numbers were indeterminable. Recapture data were insufficient to determine population estimates based on mark-recapture results and were therefore excluded from these analyses.

Nyctinomops macrotis (Gray)
Big Free-tailed Bat

Borell (1939) first reported *N. macrotis* within the current boundary of BBNP after discovering a colony in Pine Canyon. Despite the efforts of other researchers, this colony has not been located since its initial discovery. The status of this species in BBNP is uncommon according to the National Park Service (Big Bend Natural History Association, 2000). *Nyctinomops macrotis* was ranked seventh in relative abundance along with *Myotis californicus* (Table 7). However, *N. macrotis* represented only 4.3% of all captures during this survey (Tables 6). As is the case with the other free-tailed species encountered in this survey, sampling biases resulting from heavy sampling at sites frequented by this species should be considered with regard to overall abundance of this species.

This species was encountered 27 April–12 October (Fig. 27), extending the known seasonal occurrence of this bat in Texas (Fig. 2). In Texas, significant numbers of *N. macrotis* have only been taken at BBNP (Easterla, 1973*a*, 1973*b*; Milner et al., 1990; Schmidly, 1991). Historically, this species is rarely encountered across its known range in the southwestern United States, except in a few locations where it is locally abundant (Barbour and Davis, 1969). Schmidly (1974) suggested that the presence of rocky cliffs containing crevices (characteristic of many canyon walls in BBNP) is likely a limiting factor in the distribution of *N. macrotis*. The availability of suitable roosting sites throughout the Big Bend region likely influences the local abundance of *N. macrotis* in BBNP. This survey produced 85 captures of this bat at three localities in the river floodplain habitat (two sites within BBNP and one site outside the park boundary; Fig. 1 and Table 3). All captures of *N. macrotis* occurred in open riparian habitats characterized as having large water surface areas that were devoid of obstructions.

Surprisingly, no *N. macrotis* were encountered in June despite six visits to study sites frequented by *N. macrotis*. Moreover, two localities where *N. macrotis* was common, Menagerie Springs and Terlingua Abaja, were sampled year-round (excluding December) yet produced no winter captures of this species. With the exception of a single individual obtained in December in San Patricio County, there are no winter records of *N. macrotis* from Texas (Raun, 1961; Schmidly, 1991), yet it is considered a seasonal migrant throughout much of its range (Milner et al., 1990). Although the presence of *N. macrotis* in BBNP during winter has not been verified, some individuals may over-winter there, as was observed in *N. femorosaccus*. The big free-tailed bat is apparently a late flier, as most were taken from nets two to three hours after sunset, and only two individuals were encountered prior to this time.

Seventy-eight females and six males were identified (Fig. 28). Segregation of the sexes also has been observed in this species within its United States range by other investigators (Easterla, 1973*a*, 1973*b*; Milner et al., 1990). Easterla (1973*a*; 1973*b*) predominately captured females, and encountered but one adult male. We encountered 18 pregnant females (21 May–28 August), 27 lactating females (9 July–27 September),

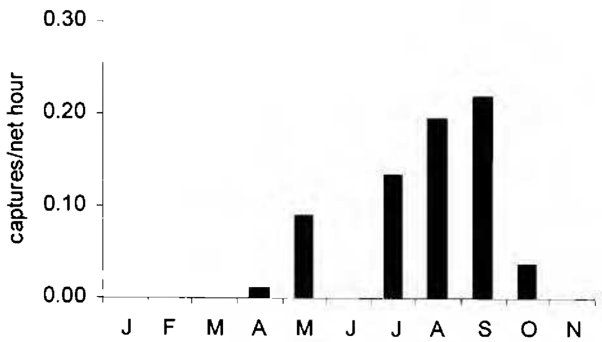

Figure 27. Seasonal distribution of *Nyctinomops macrotis* (N=85) from capture data from 17 localities in BBNP, 1996-1998 (all years combined).

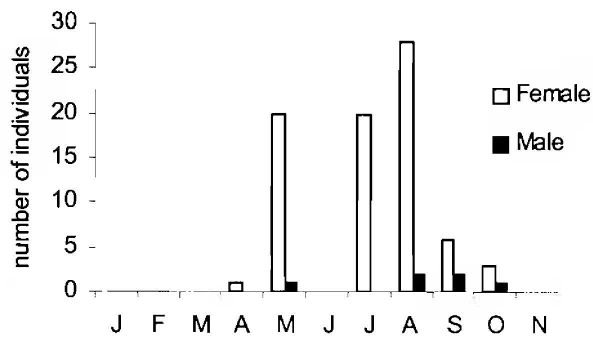

Figure 28. Seasonal distribution of male and female *Nyctinomops macrotis* in BBNP, 1996-1998 (all years combined).

and 12 post-lactating individuals (14 July–27 September; Fig. 3). One female and four male juveniles were captured between 5 August and 28 September (Fig. 3). The two adult males, captured 12 October and 27 May, showed no signs of testicular descent.

Eumops perotis (Schinz)
Western Mastiff Bat

Constantine (1961) first encountered the western mastiff bat in BBNP. *Eumops perotis* is considered as rare in Big Bend according to the National Park Service (Big Bend Natural History Association, 2000). During this investigation, this bat was ranked sixth in relative abundance (Table 7) and comprised 4.4% of all captures (Table 6). Eighty-eight individuals were captured at three sites within the river floodplain (Table 3). Large, open water sources unobstructed by vegetation were invariably used by this species. Drinking localities of this type may be preferred by western mastiff bats, since their long, narrow wings and large size make it difficult to maneuver through obstructed areas or narrow corridors (Vaughn, 1966).

Eumops perotis has a spotty distribution across the desert southwestern regions of the United States, according to collection records. It prefers rugged, rocky country where canyon crevices provide suitable roosting habitat (Barbour and Davis, 1969). This species is believed to be a year-round resident in the Trans-Pecos where individuals have been observed as early as January and as late as November (Schmidly, 1991). During this investigation, 88 *E. perotis* were taken 15 March–27 November (Fig. 29), and the loud echolocation calls characteristic of this species were often heard during winter visits. Eighty-six individuals were obtained at Menagerie Springs and Terlingua Abaja. These two localities exhibited a relatively high degree of molossid activity. Two additional individuals were captured over a smooth stretch of the Rio Grande in the Cross Canyons region of Mariscal Canyon. Only seven *E. perotis* were captured in nets prior to two hours after sunset. This supports other accounts that this species typically emerges late in the evening to forage.

The increased activity observed in November following a relative decrease in captures per net hour during September and October (Fig. 29) is puzzling. A similar trend was observed in the seasonal distributions reported in this work for two other free-tailed species (*N. femorosaccus* and *N. macrotis*). Migratory activity in *Nyctinomops* was suggested to explain their increased activity during fall. However, it is unlikely that migratory waves of *E. perotis* pass through the Big Bend region, as the area is located along the northern boundary of the species known range. In addition, *E. perotis* is believed to be a year-round resident in the region (Schmidly, 1991), and is not known to migrate (Barbour and Davis, 1969). The increased activity in fall (Fig. 29) is not strongly influenced by the presence of juveniles since only two were captured during this time. This increased activity in fall, as well as the fluctuation in activity across all seasons

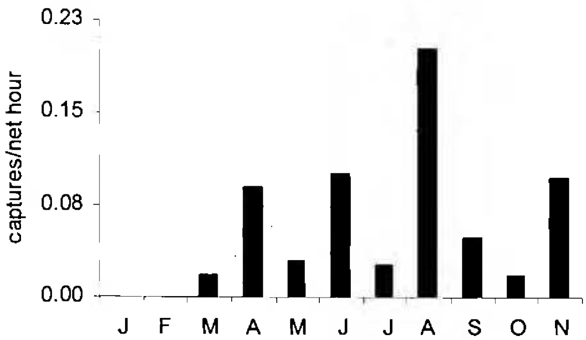

Figure 29. Seasonal distribution of *Eumops perotis* (N=88) from capture data from 17 localities in BBNP, 1996-1998 (all years combined).

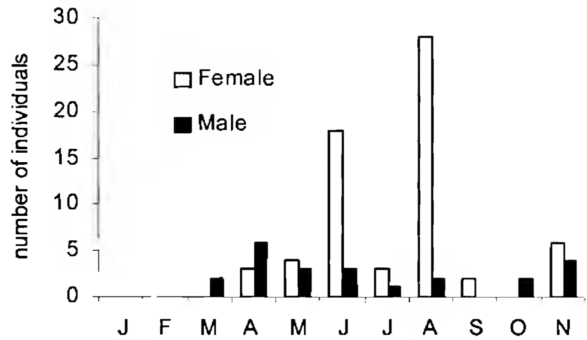

Figure 30. Seasonal distribution of male and female *Eumops perotis* in BBNP, 1996-1998 (all years combined).

remains unexplained, and may simply be an artifact of the relatively low number of captures.

Females outnumbered males nearly 3:1 (Fig. 30). Pregnant females were obtained 31 May–4 August, yet most were encountered 20 June–14 July (Fig. 3). Lactating females were captured 4–18 August, post-lactating females were only encountered on August 18, four juveniles were captured 5 August–27 September, and four sub-adults were encountered on 27 November and 28 April (Fig. 3).

Wing Morphology and Community Structure in Big Bend National Park

Variation in wing morphology is pronounced among bats and is known to affect the flight capabilities observed in different species (Vaughn, 1966; Farney and Fleharty, 1969; Findley et al., 1971). The aspect ratio of the wing is the component of wing morphology that expresses anteroposterior width of the wing. High aspect and low aspect ratios correspond to narrow and broad widths along the length of the wing, respectively. Aspect ratio is positively correlated with flight speed, and bats possessing narrow, long wings are powerful, swift fliers. Consequently, narrow wings result in the reduction of lift, and thus maneuverability is sacrificed. Broad wing width increases lift and facilitates agility and hovering ability while forfeiting speed. Generally, bats with lower wing aspect ratios are forest-dwelling species where agility is important. Species with higher aspect ratios tend to forage in open areas where obstructions are diminished (Findley et al., 1971). Members of the family Molossidae captured in this study (*T. brasiliensis*, *N. femorosaccus*, *N. macrotis* and *E. perotis*) have the highest wing aspect ratios recorded among bats, enabling them to fly long distances in a relatively short period of time (Findley et al., 1971; Wilkins, 1989). Thus, many bats in this family are known to migrate and fly long distances to forage.

Farney and Fleharty (1969) and Findley et al. (1971) report wing aspect ratios for bats other than molossids as average or below average, with molossids being well above average. Moreover, the aspect ratios of the wings of molossid species do not overlap with any other family of bats. Bats other than molossids may not be as swift or as powerful fliers because their wings lack the length and narrowness that molossids possess, but they are much more agile fliers and have increased maneuverability in relation to the Molossidae (Vaughn, 1966; Farney and Fleharty, 1969; Findley et al., 1971). Wing morphology therefore likely influences the type of water source a bat can utilize for drinking or foraging in a given habitat. The following is a discussion of how structural features of water sources in BBNP are associated with the bat community found at a particular locality.

Jaccard's indices for the 17 sites sampled in this survey (summarized in Table 2) are presented in matrix form in Table 9. These values illustrate the relative similarity in chiropteran community structure between each pair of sites sampled in BBNP during this study. The Jaccard's coefficient ranges in value from 0 to 1 with 1 indicating complete similarity between

Table 9. Matrix depicting the similarity and diversity of chiropteran fauna among 17 netting localities in Big Bend National Park. Bold-faced numbers represent the number of species of bats encountered at a given locality. Numbers left of the diagonal represent Jaccard's coefficient of similarity between two localities. Numbers right of the boldface diagonal depict number of bat species shared between each pair of localities.

Netting Site	MS	GS	TA	ET	BS	CC	CF	TC at RG	GP	FC	CT	CS	DFC	EC	TC at 170	DFR	TC at HS
Menagerie Springs	**13**	8	9	7	7	6	6	7	5	3	4	3	2	2	2	2	1
Glenn Springs	0.50	**12**	7	9	7	4	7	6	5	4	4	4	1	2	1	2	1
Terlingua Abaja	0.64	0.50	**10**	6	6	5	5	5	4	2	3	3	2	2	2	2	1
Ernst Tinaja	0.44	0.67	0.46	**10**	6	3	7	7	5	5	4	3	3	2	1	2	1
Banta Shut-in	0.54	0.50	0.55	0.60	**8**	4	5	5	5	2	4	3	2	2	1	2	1
Cross Canyons	0.43	0.21	0.42	0.23	0.36	**7**	2	3	2	1	2	1	1	1	1	1	1
Cattail Falls	0.43	0.42	0.42	0.70	0.50	0.17	**7**	4	5	4	4	3	2	2	1	2	0
Terlingua Cr. at R.G.	0.54	0.57	0.42	0.54	0.56	0.27	0.40	**7**	3	2	3	1	1	0	1	1	1
Gambusia Pools	0.38	0.25	0.36	0.50	0.63	0.20	0.71	0.33	**5**	2	4	3	2	2	1	2	1
Fresno Creek	0.18	0.25	0.15	0.50	0.15	0.09	0.5	0.22	0.25	**5**	2	1	2	1	0	1	0
Carlotta Tinaja	0.31	0.57	0.27	0.44	0.57	0.25	0.5	0.38	0.80	0.29	**4**	2	2	1	1	2	1
Croton Springs	0.21	0.27	0.27	0.27	0.33	0.10	0.38	0.10	0.50	0.13	0.33	**4**	2	2	0	2	0
Dagger Flat Canyon	0.15	0.08	0.20	0.30	0.22	0.13	0.25	0.11	0.33	0.33	0.40	0.40	**3**	1	0	2	0
Ernst Canyon	0.15	0.20	0.20	0.20	0.25	0.13	0.29	0	0.40	0.17	0.20	0.50	0.25	**2**	0	1	0
Terlingua Cr. & 170	0.15	0	0.20	0.09	0.11	0.13	0.13	0.13	0.17	0	0.20	0	0	0	**2**	0	1
Dagger Flat Road	0.15	0.09	0.20	0.20	0.25	0.13	0.29	0.13	0.67	0.17	0.50	0.50	0.67	0.33	0	**2**	0
Tornillo Creek at HS	0.08	0	0.10	0.10	0.13	0.14	0	0.14	0.20	0	0.25	0	0	0	0.50	0	**1**

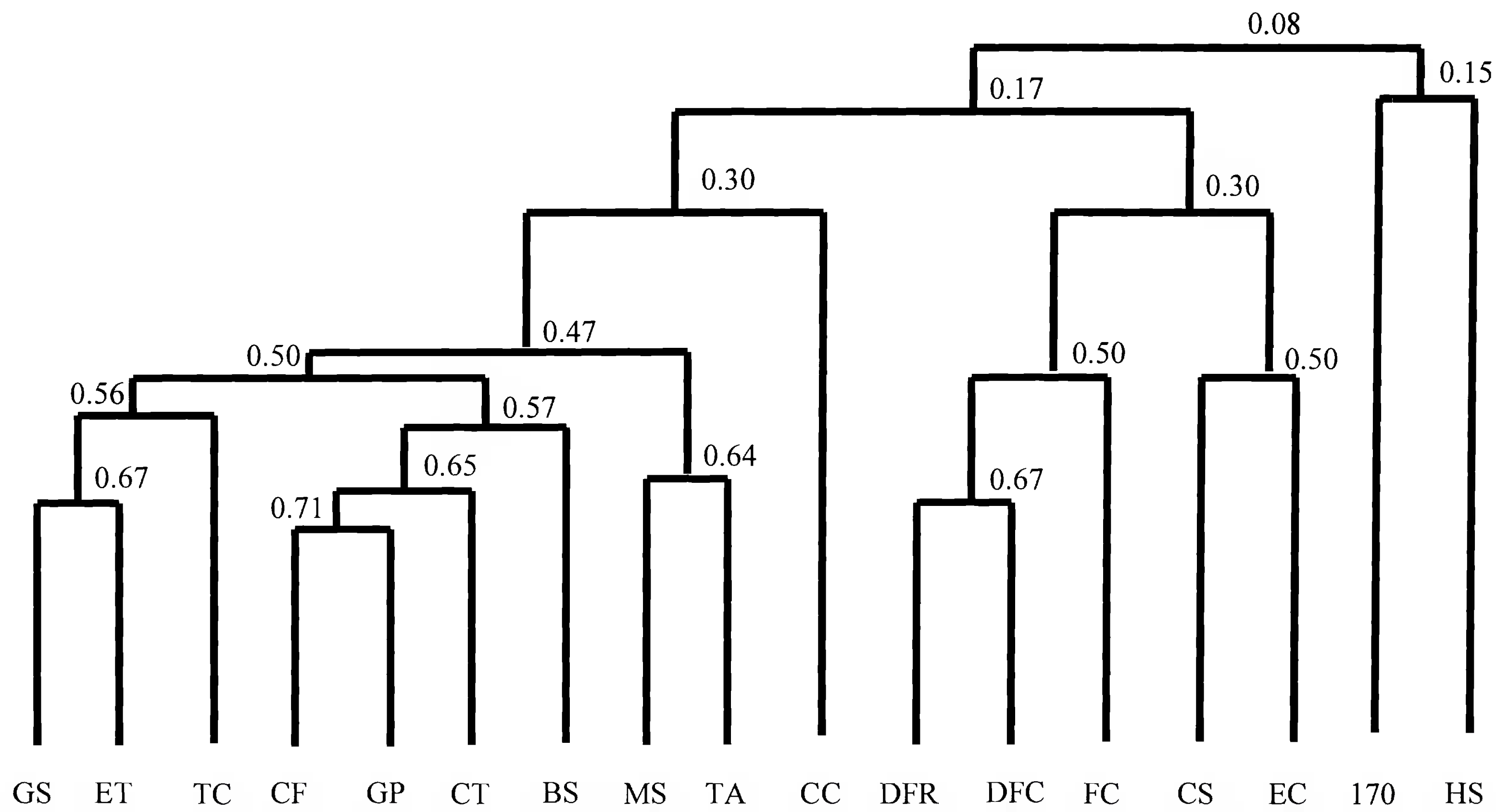

Figure 31. Average-linkage cluster analysis of the species composition of bats at 17 netting localities in Big Bend National Park based on Jaccard's coefficient of similarity. Branch distances are not to scale. GS = Glenn Springs, ET = Ernst Tinaja, TC = Terlingua Creek at Rio Grande, CF = Cattail Falls, GP = Gambusia Pools (Rio Grande Village), CT = Carlotta Tinaja, BS = Banta Shut-in, MS = Menagerie Springs, TA = Terlingua Abaja, CC = Cross Canyons, DFR = Dagger Flat Road, DFC = Dagger Flat Canyon, FC = Fresno Creek, CS = Croton Springs, EC = Ernst Canyon, 170 = Terlingua Creek at Hwy. 170, and HS = Tornillo Creek at Hot Springs.

two sampling localities. A clustering analysis was performed on the matrix and is presented in Figure 31 as a branching tree diagram clustering the sites most similar in the community structure of the bats encountered at these localities. The similarity matrix presented in Table 9 also indicates the number of species of bats found at a given site as a measure of diversity. Diversity at a particular site is influenced by the amount of the time spent sampling a given locality, therefore data from the sparsely sampled sites do not necessarily reflect all of the bats that might utilize those localities. For this reason, a clustering analysis was performed a second time including only those sites that were sampled on three or more occasions (Fig. 32).

The Glenn Springs and Ernst Tinaja localities share the highest Jaccard's index with 67% similarity (Table 9 and Fig. 32). The two sites are located approximately 30 kilometers apart and are structurally very similar in having water sources crowded by close canyon walls (Glenn Springs is also overgrown with vegetation). These two sites have nine species of bats in common.

The relatively high similarity in species composition at Glenn Springs and Ernst Tinaja is likely due to several factors. First, both sites were sampled relatively evenly, with Glenn Springs and Ernst Tinaja sampled 10 and 12 times, respectively. Second, both are situated in the shrub desert habitat, therefore species showing a preference for lowland habitats may likely be found at either site. Third, although water levels were observed to fluctuate annually at both sites, they were both generally reliable sources of water year-round over the course of this investigation. Finally, bats having average or below average wing aspect ratios, allowing ease in navigation through the constricted corridors that are characteristic of both localities, were commonly obtained at both. Given the confined water surface area at Ernst Tinaja and Glenn Springs, it is not surprising that the larger three of the four species of molossid bats known from BBNP were not captured at either site (Table 4).

Terlingua Abaja and Menagerie Springs are joined in the cluster by a 60% similarity in species composition (Table 9 and Fig. 32), and share many structural similarities in their respective water sources. Both localities invariably consisted of long, wide pools with banks unobstructed by dense vegetation during this survey. These structural features essentially provided a "runway" of open water that was easily accessible to flying bats. Terlingua Abaja and Menagerie Springs are located on opposite sides of BBNP over 50 kilometers apart, and lie along BBNP's two primary drainages, Terlingua and Tornillo Creeks, respectively (Fig. 1). Molossids accounted for 90% of all captures at both Terlingua Abaja and Menagerie Springs during 45 sampling visits, and many other lowland species were not taken at these sites (Table 3). Ninety-eight percent of all *N. femorosaccus*, *N. macrotis* and *E. perotis* and 90% of all *T. brasiliensis* captured during this study were encountered at Menagerie Springs and Terlingua Abaja, collectively. The dominant presence of *N. femorosaccus*, *N. macrotis* and *E. perotis*, which were rarely encountered elsewhere (Tables 3, 4 and 5), undoubtedly influenced the similarity in species composition exhibited between these two localities. With decreased agility as a result of wing morphology, *T. brasiliensis*, *N. femorosaccus*, *N. macrotis* and *E. perotis* demonstrated a preference to Terlingua Abaja and Menagerie Springs among all other localities sampled. *Tadarida brasiliensis* was frequently captured at sites having more restricted waterways, yet its small size relative to the other molossids allows this species more maneuverability.

Species of free-tailed bats other than *T. brasiliensis* were rarely encountered at any locality except Terlingua Abaja and Menagerie Springs. Cross Canyons on the Rio Grande, the intersection of Terlingua Creek and the Rio Grande, and the intersection of Highway 170 and Terlingua Creek are additional sites with large water surface areas having few obstructions. Work conducted at these localities produced very few captures of *E. perotis*, *N. femorosaccus* and *N. macrotis* (Table 3). The swift currents typical of these waters may explain the reduced rate of molossid captures at these sites. These three sites are located on the Rio Grande or along Terlingua Creek where the flow of the water was swift accompanied by a shallow depth.

Banta Shut-in is a remote lowland site where the water levels varied dramatically between sampling visits. This locality consists of a deep, narrow canyon along the Tornillo Creek drainage where water forced from beneath the ground typically pooled only during

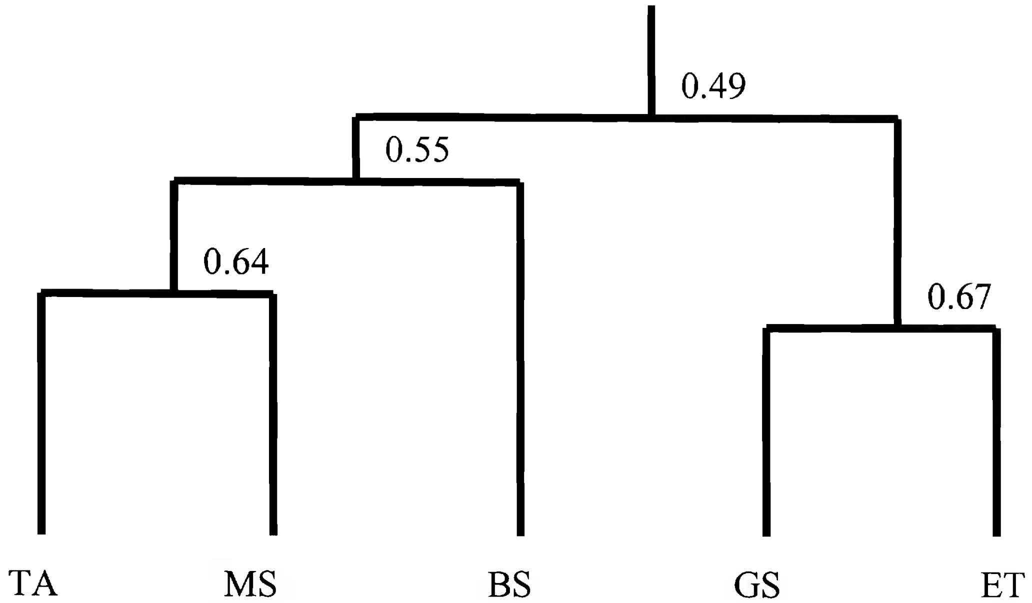

Figure 32. Average-linkage cluster analysis of the species composition of bats among five frequently sampled localities in Big Bend National Park based on Jaccard's coefficient of similarity. Branch distances are not to scale. TA = Terlingua Abaja, MS = Menagerie Springs, BS = Banta Shut-in, GS = Glenn Springs, and ET = Ernst Tinaja.

the wetter and cooler months of the year during this study. The available surface water present during sampling periods appeared to impact the netting success at this site. Although Banta Shut-in is more similar to Glenn Springs and Ernst Tinaja in both water surface and surrounding topographical features, the third node of the tree in Fig. 32 clusters Banta Shut-in with Menagerie Springs and Terlingua Abaja. The third node represents a 55% similarity value (Table 9). Sampling at Banta Shut-in produced only two captures of *N. femorosaccus*, and represents the single locality having a confined water source where species of molossids other than *T. brasiliensis* were netted (Table 3).

The Jaccard's indices of similarity presented here are binary in nature, and are thus based only on the presence or absence of a particular species at a locality. This analysis method is not sensitive to differences in the number of individuals among species. An application of techniques that consider abundance data and presence-absence data may reveal finer details in the differences in community structure among the sampling localities discussed herein.

Certainly the amount of sampling conducted at Menagerie Springs and Terlingua Abaja likely influenced the number of molossids as well and the number of species encountered at these sites. Although uneven sampling across localities was conducted, other heavily sampled sites (Ernst Tinaja, Glenn Springs and Banta Shut-in) lacked a high rate of captures of molossids, despite their close proximity to molossid-dominated sites, or molossid roosts, as is the case at Banta Shut-in (Tables 3 and 4; Fig. 1). These three localities displayed crowded conditions around the water source and were visited by a greater number of species with the ability to navigate through confined corridors. The low rate of capture, or altogether absence of free-tailed species (exclusive of *T. brasiliensis*) at Ernst Tinaja, Glenn Springs, Banta Shut-in, and other sites should be considered as a consequence of the inaccessibility of the water's surface at these sites to these fast-flying molossid species due to dense vegetation and/or narrow canyons. With the exception of *T. brasiliensis*, the molossids encountered during this survey (*N. femorosaccus*, *N. macrotis* and *E. perotis*) exhibited the greatest degree of preference in a particular water source relative to other species of bats, and are herein considered as "open water specialists." Interestingly, Menagerie Springs was the only large, free standing, year-round water source in the eastern half of the park during this investigation, yet species of bats other than molossids that were common at nearby sites were not obtained at the Menagerie Springs locality to the degree that molossids were encountered. One explanation of this observation is competition for "air space" at Menagerie Springs and Terlingua Abaja between molossids and other species of bats. We suspect that smaller species of bats were somehow "excluded" from these drinking sources, possibly in an attempt to avoid collisions with the swift-flying molossids.

In summary, specific structural characteristics inherent to each water source probably play a large role in water source selection among species of bats in BBNP. Other factors such as suitable roosting sites, distance from roosts to drinking sources, climate, topography, elevation, vegetation, and prey preferences also influence the distribution and community structure of bats in BBNP.

Observations on Changes in Community Structure

The data presented in Table 10 illustrate several noticeable differences in the relative abundance of lowland bat species obtained during this study and Easterla's (1973*a;* 1973*b*) work in BBNP. With the exception of *L. cinereus* and *L. xanthinus*, all other species sampled in the lowlands displayed a reduced relative abundance in this study compared to Easterla's (1973*a;* 1973*b*). Comparatively, 15 of the 18 lowland species of bats were encountered more frequently per net night 30 years ago. Although the abundance rankings of *T. brasiliensis, A. pallidus*, and *P. hesperus* in the two studies differ, these were the three most abundant species in both surveys, however, *A. pallidus* and *P. hesperus* were encountered during this study in half as many nights compared to previous work (Easterla, 1973*a;* 1973*b*).

Molossids as a group were ranked among the seven most frequently encountered species of bats during both investigations. The differences in abundance observed in *N. macrotis* during the two surveys are interesting since molossid-dominated sites were sampled in near equal proportions during both investigations. Easterla (1973*a;* 1973*b*) captured *N. macrotis* during 50% of netting nights while we encountered *N. macrotis* during 21% of visits to capture sites, yet Easterla obtained *N. femorosaccus* at relatively the same frequency as in this study (35% and 39% of netting nights, respectively). Easterla (1973*a;* 1973*b*) ranked *N. macrotis* fifth in relative abundance during his investigation in BBNP. Interestingly, a locality surveyed by Easterla's (1973*a;* 1973*b*) known as X-site (locality undisclosed) shares a similar species composition with Menagerie Springs (reported herein). The four free-tailed species that occur in BBNP (*T. brasiliensis, N. femorosaccus, N. macrotis*, and *E. perotis*) comprise over 73% of all captures at X-site (Easterla 1973*a;* 1973*b*), and 90% of all captures at the Menagerie Springs locality surveyed in this work. Both sites share a comparatively high concentration of molossids with respect to other sites sampled in either survey. *Nyctinomops macrotis*, *N. femorosaccus*, and *E. perotis* were rarely encountered at sites, excluding molossid-dominated sites, reported in both studies (Easterla, 1973*a*, 1973*b*; this study). Easterla (1973*a;* 1973*b*) captured considerably more *N. macrotis* (411), yet considerably less *N. femorosaccus* (89) at molossid-dominated sites compared to this study (with a proportionate amount of sampling effort). Further analysis is required to confirm any significant changes in the abundance of either species in BBNP over the last 30 years. Possible scenarios for the difference in abundance of *N. femorosaccus* and *N. macrotis* observed in these two BBNP studies however may be inferred. A closer proximity of sites exhibiting a high rate of molossid captures to either a *N. macrotis* or a *N. femorosaccus* roost is plausible, or perhaps the differences can simply be explained by annual population fluctuations. Other investigators (Barbour and Davis, 1969; Easterla, 1973*a;* 1973*b*) have observed this type of discontinuity in the annual activity of *N. macrotis*.

Another obvious discrepancy between these two data sets was observed in *E. maculatum*. This species was encountered in previous work (Easterla, 1973*a;* 1973*b*) during 32% of netting nights, yet it was obtained during only 2% of netting nights during this study (Table 10). Table 10 shows an evident difference in the abundance of *M. yumanensis*, as it was obtained on more sampling nights during the study conducted over 30 years ago. In the recent investigation, *L. nivalis* comparatively exhibited a ten-fold decrease in encounter frequency, *M. velifer* encounters decreased by half, and we found *L. cinereus* five times more frequently per net night compared to prior work

Table 10. Comparison of the relative abundances of lowland species of bats during two studies in BBNP (Easterla, 1973a; 1973b; and this study). Species are ordered from most to least abundant.

Species Captured (1996-1998)	% Encounter Frequency	Species Captured (Easterla, 1973*a*; 1973*b*)	% Encounter Frequency
Tadarida brasiliensis	55	*Antrozous pallidus*	89
Antrozous pallidus	48	*Pipistrellus hesperus*	76
Pipistrellus hesperus	47	*Tadarida brasiliensis*	58
Nyctinomops femorosaccus	35	*Myotis yumanensis*	57
Mormoops megalophylla	28	*Nyctinomops macrotis*	50
Eumops perotis	24	*Nyctinomops femorosaccus*	39
Nyctinomops macrotis	21	*Eumops perotis*	36
Myotis californicus	21	*Euderma maculatum*	32
Lasiurus cinereus	15	*Mormoops megalophylla*	32
Eptesicus fuscus	14	*Myotis velifer*	32
Myotis yumanensis	14	*Eptesicus fuscus*	26
Myotis velifer	13	*Myotis californicus*	15
Corynorhinus townsendii	7	*Leptonycteris nivalis*	11
Lasiurus xanthinus	4	*Corynorhinus townsendii*	10
Euderma maculatum	2	*Myotis thysanodes*	7
Myotis thysanodes	2	*Lasiurus cinereus*	3
Leptonycteris nivalis	1	*Lasiurus xanthinus*	0

Note: Encounter frequency is a measure of relative abundance and was determined by the percentage of netting nights each species was encountered.

(Table 10). Moreover, *L. xanthinus* was not encountered during previous investigations of the bats in BBNP.

Factors such as annual fluctuations in population, seasonal migration, and sampling biases (both seasonal and spatial) may contribute to the differences in abundance observed between these two studies. Further analysis of the two data sets is needed to determine any substantial changes in the chiropteran community structure over the last 30 years in Big Bend National Park.

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APPENDIX I
GAZETTEER

Universal Transverse Mercator (UTM) coordinates for the localities sampled. All localities were located in UTM zone 13. Elevations are given in meters.

Netting Localities	UTM Coordinates	Elevation
Banta Shut-in	686183E; 3246150N	Not Recorded
Carlotta Tinaja	690881E; 3240513N	Not Recorded
Cattail Falls	661593E; 3239324N	Not Recorded
Cross Canyon	682079E; 3207628N	Not Recorded
Croton Springs	660553E; 3246778N	Not Recorded
Dagger Flat Canyon	693095E; 3272890N	1060
Dagger Flat Road	687522E; 3263850N	1053+/-58
Ernst Canyon	693528E; 3238067N	1590
Ernst Tinaja	694619E; 3239744N	1590
Fresno Creek	665841E; 3231598N	Not Recorded
Gambusia Pools	698958E; 3229574N	607+/-149
Glenn Springs	679148E; 3228692N	741+/-87
Terlingua Creek at Hwy. 170	640365E; 3244734N	Not Recorded
Menagerie Springs	684070E; 3252950N	904+/-149
Terlingua Abaja	635501E; 3231031N	662+/-49
Terlingua Creek at Santa Elena	634985E; 3227396N	Not Recorded
Tornillo Creek at Hot Springs	694534E; 3229226N	520

APPENDIX II
LOG OF SPECIMENS COLLECTED

Species	Sex	Date Collected	ASNHC Museum Number	UTM Coordinates Zone 13
Eumops perotis	Female	17 Aug 1996	11526	635501E; 3252950N
Eumops perotis	Female	26 Jun 1997	11527	635501E; 3252950N
Lasiurus xanthinus	Male	12 Oct 1996	11507	635501E; 3252950N
Lasiurus xanthinus	Male	27 Sep 1997	11506	635501E; 3252950N
Mormoops megalophylla	Female	18 May 1996	11501	679148E; 3228692N
Myotis californicus	Female	21 Jun 1996	11508	694619E; 3239744N
Myotis californicus	Female	21 Mar 1996	11514	686183E; 3246150N
Myotis californicus	Male	21 Mar 1996	11513	686183E; 3246150N
Myotis californicus	Male	23 Jan 1998	11515	684070E; 3252950N
Myotis californicus	Female	29 Apr 1998	11509	694619E; 3239744N
Myotis thysanodes	Female	23 May 1998	11516	679148E; 3228692N
Myotis yumanensis	Male	29 Jul 1997	11520	635501E; 3231031N
Myotis yumanensis	Male	1 Mar 1998	11521	635501E; 3231031N
Nyctinomops femorosaccus	Female	11 Oct 1996	11529	684070E; 3252950N
Nyctinomops femorosaccus	Female	14 Jul 1997	11532	684070E; 3252950N
Nyctinomops femorosaccus	Male	14 Jul 1997	11530	684070E; 3252950N
Tadarida brasiliensis	Male	20 Mar 1996	11536	635501E; 3231031N
Tadarida brasiliensis	Female	27 Nov 1997	11537	684070E; 3252950N

APPENDIX III
EXTERNAL MEASUREMENTS

Means, standard deviations, and ranges of external measurements for 17 species of bats from Big Bend National Park (1996-1998). These data were obtained from live animals prior to the release of the animal and may include measurements obtained from juveniles. Weights were measured in grams. Lengths were measured in millimeters.

Species	Weight	Forearm	Hind Foot	Ear
Mormoops megalophylla				
	n=85	n=85	n=87	
Female	17.65±2.52	55.44±1.22	10.50±0.93	*
	10.0–23.0	51.7–58.3	7.2–12.0	
	n=8	n=8	n=7	
Male	17.0±1.77	55.84±0.76	10.21±1.33	*
	14.0–19.0	54.6–57.0	8.0–12.4	
Leptonycteris nivalis				
	n=2	n=2	n=2	
Female	36.0±1.41	56.95±0.35	14.20±0.99	*
	35.0–37.0	56.7–57.2	13.5–14.9	
Myotis yumanensis				
	n=18	n=18	n=18	n=18
Female	5.61±1.69	33.26±0.78	7.88±0.92	10.79±1.37
	3.0–9.0	32.1–34.5	5.7–9.5	8.0–13.3
	n=22	n=24	n=24	n=24
Male	4.82±0.96	33.10±0.93	7.97±0.72	11.32±1.40
	3.0–7.0	31.0–35.1	7.0–9.8	8.8–15.5
Myotis velifer				
	n=21	n=23	n=23	n=23
Female	8.67±1.67	43.38±1.03	8.93±1.10	15.40±1.83
	5.0–11.3	41.6–45.3	6.7–10.8	12.0–19.8
	n=11	n=11	n=11	n=10
Male	8.09±0.74	42.57±0.97	9.19±0.90	13.17±2.31
	7.0–9.0	40.4–43.7	7.5–10.2	9.9–18.0
Myotis thysanodes				
	n=1	n=1	n=1	n=1
Female	7.0	41.9	10.1	15.6
	n=1	n=1	n=1	n=1
Male	7.5	42.1	9.9	13.3
Myotis californicus				
	n=18	n=18	n=18	n=18
Female	4.69±1.35	32.38±0.91	6.62±0.59	12.18±1.13
	3.0–8.0	30.2–34.0	5.8–7.7	10.0–14.3
	n=10	n=10	n=10	n=10
Male	4.05±0.44	31.88±0.83	6.40±1.03	11.70±0.97
	3.5–5.0	30.8–33.0	4.3–7.9	10.2–13.0
Pipistrellus hesperus				
	n=92	n=90	n=90	n=88
Female	5.06±1.25	32.06±1.23	5.98±0.64	10.74±1.11
	3.0–9.0	28.5–39.0	3.7–7.9	8.8–13.0
	n=66	n=67	n=65	n=65
Male	3.85±0.75	30.65±1.54	5.88±0.60	10.41±1.06
	2.0–5.0	28.1–39.7	4.0–7.2	8.5–13.0

Appendix III. (continued).

Species	Weight	Forearm	Hind Foot	Ear
Eptesicus fuscus				
Female	n=18 17.85±2.24 14.0–20.0	n=18 49.60±1.37 46.3–51.6	n=17 10.07±0.81 8.6–11.4	n=17 14.82±1.89 11.4–17.8
Male	n=11 16.09±2.59 13.0–20.0	n=11 48.05±1.24 46.1–49.5	n=11 10.17±0.74 8.6–11.4	n=11 14.24±2.72 7.2–16.9
Lasiurus cinereus				
Female	n=5 30.00±4.85 26.0–37.0	n=5 55.06±1.13 53.5–56.4	n=3 11.83±0.86 10.9–12.6	n=3 15.73±1.64 14.5–17.6
Male	n=15 22.53±5.00 18.0–38.0	n=17 52.41±1.13 50.5–55.0	n=16 11.07±0.95 9.2–12.7	n=15 14.84±1.35 11.8–17.0
Lasiurus xanthinus				
Female	n=1 19.0	n=1 45.0	n=1 10.4	n=1 14.5
Male	n=3 13.67±1.53 12.0–15.0	n=3 44.20±0.79 43.3–44.8	n=3 9.43±1.02 8.7–10.6	n=3 15.03±1.93 13.5–17.2
Euderma maculatum				
Male	n=2 15.50±3.54 13.0–18.0	n=2 51.90±0.57 51.5–52.3	n=2 10.70±0.00 10.7	n=2 36.80±2.83 34.8–38.8
Corynorhinus townsendii				
Female	n=10 10.05±1.57 9.0–14.0	n=10 43.13±0.40 42.5–43.7	n=10 9.21±0.53 8.5–10.2	n=10 33.14±1.35 31.1–35.2
Male	n=7 7.75±0.76 7.0–9.0	n=7 41.71±1.35 40.1–43.7	n=7 9.43±0.95 7.7–10.3	n=7 33.13±1.66 31.5±36.4
Antrozous pallidus				
Female	n=136 15.03±2.80 8.0–25.0	n=141 50.89±1.75 41.5–55.2	n=130 10.77±0.87 8.0–13.0	n=133 25.35±2.20 17.4–34.9
Male	n=97 12.90±1.72 8.0–17.0	n=101 50.42±1.63 45.9–55.2	n=98 10.62±0.73 8.5–12.3	n=99 24.90±2.17 18.0–36.9
Tadarida brasiliensis				
Female	n=102 11.34±1.76 8.0–18.0	n=102 43.06±1.25 40.3–46.4	n=94 8.38±1.04 5.8–10.6	n=92 12.82±2.15 8.2–16.3
Male	n=197 10.92±1.66 6.0–18.0	n=202 42.79±1.08 39.3–46.2	n=175 8.54±0.99 5.7–11.0	n=174 13.13±1.88 8.3–17.8
Nyctinomops femorosaccus				
Female	n=171 15.87±2.41 9.0–24.0	n=173 47.01±0.98 44.4–50.9	n=170 9.14±0.85 6.5–11.1	n=157 15.80±1.74 9.7–20.1
Male	n=79 15.53±2.31 10.0–26.0	n=81 47.35±1.10 41.8–49.5	n=81 9.37±0.91 7.4–12.0	n=74 16.29±1.45 12.5–20.6

Appendix III. (continued).

Species	Weight	Forearm	Hind Foot	Ear
Nyctinomops macrotis				
	n=77	n=78	n=78	n=78
Female	28.46±2.56	61.32±1.38	10.71±0.91	21.24±1.56
	23.0–37.0	58.0–65.1	8.3–12.5	17.5–25.0
	n=6	n=6	n=6	n=6
Male	25.33±2.73	62.00±1.30	10.62±1.25	20.70±1.16
	20.0–27.0	60.6–64.4	8.5–11.8	19.1–22.4
Eumops perotis				
	n=61	n=63	n=63	n=61
Female	70.07±5.40	77.72±1.29	15.54±1.44	28.87±2.63
	53.0–81.0	75.5–81.1	12.0–18.0	23.6–33.5
	n=22	n=23	n=23	n=22
Male	71.59±9.54	79.29±2.42	16.02±1.54	31.75±3.73
	54.0–86.0	71.3–84.1	11.4–17.7	20.4–36.8

* no data were obtained for these characters